

1

00:00:00,000 --> 00:00:02,833
(inspiring music)

2

00:00:08,940 --> 00:00:12,300
- Hello and welcome to
Conversations at the Perimeter.

3

00:00:12,300 --> 00:00:14,220
Today, we're so excited to share with you

4

00:00:14,220 --> 00:00:17,130
this conversation with Gunpathy Baskaran.

5

00:00:17,130 --> 00:00:20,100
He's based out of the Institute
of Mathematical Sciences

6

00:00:20,100 --> 00:00:23,520
and the Indian Institute of
Technology in Chennai, India

7

00:00:23,520 --> 00:00:24,390
and we're so lucky

8

00:00:24,390 --> 00:00:26,610
that he visits Perimeter
Institute regularly

9

00:00:26,610 --> 00:00:29,490
as a distinguished
visiting research chair.

10

00:00:29,490 --> 00:00:30,810
- Baskaran is one of the
most interesting people

11

00:00:30,810 --> 00:00:32,400
I think I've ever talked to.

12
00:00:32,400 --> 00:00:35,430
He's not only a fascinating scientist

13
00:00:35,430 --> 00:00:36,540
who's research delves

14
00:00:36,540 --> 00:00:40,470
into condensed matter
physics and superconductivity

15
00:00:40,470 --> 00:00:43,050
and even the concepts of quantum biology,

16
00:00:43,050 --> 00:00:45,030
but he's just sort of a master storyteller

17
00:00:45,030 --> 00:00:47,820
whose enthusiasm and passion for science

18
00:00:47,820 --> 00:00:49,650
is really infectious.

19
00:00:49,650 --> 00:00:51,120
- I think it's rare to meet a physicist

20
00:00:51,120 --> 00:00:52,800
who's such a great storyteller,

21
00:00:52,800 --> 00:00:54,180
and I loved hearing stories

22
00:00:54,180 --> 00:00:55,860
about the role that collaboration

23
00:00:55,860 --> 00:00:57,420
has played throughout his career

24

00:00:57,420 --> 00:01:00,420
and also about why he loves
having discussions with students

25
00:01:00,420 --> 00:01:01,830
to inspire his research.

26
00:01:01,830 --> 00:01:03,090
- And what really comes across too

27
00:01:03,090 --> 00:01:04,620
is the gratitude that he has

28
00:01:04,620 --> 00:01:07,230
for the people that have
helped him along his journey

29
00:01:07,230 --> 00:01:08,880
and now he's trying to pay that forward.

30
00:01:08,880 --> 00:01:11,190
He's very passionate about supporting

31
00:01:11,190 --> 00:01:14,310
opportunities for young scientists
in the developing world,

32
00:01:14,310 --> 00:01:17,670
and he speaks quite passionately
about those opportunities

33
00:01:17,670 --> 00:01:19,680
and what they mean for young researchers

34
00:01:19,680 --> 00:01:21,630
trying to pursue big questions.

35
00:01:21,630 --> 00:01:22,860
- So without further ado,

36

00:01:22,860 --> 00:01:25,473

let's step inside the
perimeter with Baskaran.

37

00:01:29,070 --> 00:01:30,150

So, hi Baskaran.

38

00:01:30,150 --> 00:01:32,991

Thank you so much for
sitting down with us today.

39

00:01:32,991 --> 00:01:35,760

- So thank you Lauren and thank you Colin

40

00:01:35,760 --> 00:01:36,593

for inviting me.

41

00:01:36,593 --> 00:01:37,426

It's a pleasure to be here.

42

00:01:37,426 --> 00:01:40,470

- So you have a unique
position here at Perimeter.

43

00:01:40,470 --> 00:01:43,230

You're a distinguished
visiting research chair.

44

00:01:43,230 --> 00:01:45,597

And so that means you're
not here all of the time,

45

00:01:45,597 --> 00:01:48,270

but I know you visit here very frequently

46

00:01:48,270 --> 00:01:51,180

and I think your current
visit is ending tomorrow.

47

00:01:51,180 --> 00:01:53,460

So I wanted to start out by asking you

48

00:01:53,460 --> 00:01:55,770

if you could tell us a
little bit about this visit

49

00:01:55,770 --> 00:01:57,840

and some of the highlights.

50

00:01:57,840 --> 00:01:59,520

- I was missing Perimeter Institute

51

00:01:59,520 --> 00:02:00,900

for the last three years

52

00:02:00,900 --> 00:02:04,530

so I was making a personal
visit to Los Angeles.

53

00:02:04,530 --> 00:02:07,290

I thought I'll visit my
daughter there for a month.

54

00:02:07,290 --> 00:02:10,500

Then because of COVID, we
stayed happily for four months.

55

00:02:10,500 --> 00:02:13,053

Then I heard the news
that Perimeter is opening.

56

00:02:13,053 --> 00:02:15,877

So immediately I wrote
Perimeter and I'm here.

57

00:02:16,784 --> 00:02:19,230

And I'm very honored to be

associated with Perimeter

58

00:02:19,230 --> 00:02:20,880

for nearly a dozen years.

59

00:02:20,880 --> 00:02:21,990

It's a great place.

60

00:02:21,990 --> 00:02:23,327

I tell wherever I go.

61

00:02:23,327 --> 00:02:26,220

It's a great example to be emulated,

62

00:02:26,220 --> 00:02:28,110

from the way it's funded

63

00:02:28,110 --> 00:02:31,020

and the way theoretical
sciences are practiced.

64

00:02:31,020 --> 00:02:34,620

So it's really an open
ended respect for science

65

00:02:34,620 --> 00:02:37,080

as something that helps humanity.

66

00:02:37,080 --> 00:02:40,230

So yeah, respect is
shown in real terms here.

67

00:02:40,230 --> 00:02:44,280

So I like this place and I have
been coming very regularly.

68

00:02:44,280 --> 00:02:45,720

In terms of my research activities,

69

00:02:45,720 --> 00:02:47,520
it really helped me a lot

70

00:02:47,520 --> 00:02:50,010
because I meet a lot of people,
meet a lot of young people.

71

00:02:50,010 --> 00:02:51,090
- Can you explain that a bit,

72

00:02:51,090 --> 00:02:53,490
why meeting people face to face

73

00:02:53,490 --> 00:02:56,580
and traveling essentially
halfway around the world to do so

74

00:02:56,580 --> 00:02:58,260
is important to your work?

75

00:02:58,260 --> 00:03:00,240
You mentioned young people in specific.

76

00:03:00,240 --> 00:03:01,353
Why young people?

77

00:03:02,520 --> 00:03:04,890
- Theoretical physics by definition

78

00:03:04,890 --> 00:03:06,960
involves lots of imagination

79

00:03:06,960 --> 00:03:09,570
and young people have
definitely a lot of imagination.

80

00:03:09,570 --> 00:03:14,446
I'm reminded of one

quotation from Picasso.

81

00:03:14,446 --> 00:03:15,780

He started as a realistic painter.

82

00:03:15,780 --> 00:03:16,640

Then he got bored with it,

83

00:03:16,640 --> 00:03:18,870

he started painting abstract pictures.

84

00:03:18,870 --> 00:03:20,640

Apparently, one of his aims was

85

00:03:20,640 --> 00:03:23,430

that he wants to be as
imaginative as children

86

00:03:23,430 --> 00:03:25,530

and he could never beat them.

87

00:03:25,530 --> 00:03:30,026

In his mind, he wanted to
mimic them and copy them,

88

00:03:30,026 --> 00:03:31,470

but he could never beat their imagination.

89

00:03:31,470 --> 00:03:34,110

So in the same way, when
you meet young people here,

90

00:03:34,110 --> 00:03:37,230

they have wild ideas, it's
nice to talk about it.

91

00:03:37,230 --> 00:03:39,840

Many of them these days
are extremely mathematical

92

00:03:39,840 --> 00:03:42,060

because mathematics is very enticing.

93

00:03:42,060 --> 00:03:44,130

Physics is an experimental science.

94

00:03:44,130 --> 00:03:47,550

Mathematics and physics
experiments go hand in hand.

95

00:03:47,550 --> 00:03:49,053

When you meet young people,

96

00:03:49,053 --> 00:03:51,084

there are people who are
motivated by experiments,

97

00:03:51,084 --> 00:03:51,917

there are people who are motivated

98

00:03:51,917 --> 00:03:53,850

by theories and mathematics.

99

00:03:53,850 --> 00:03:54,867

So it's fun to see.

100

00:03:54,867 --> 00:03:56,850

The variety is mind boggling.

101

00:03:56,850 --> 00:03:59,460

I always compare it to
the wild flowers I see

102

00:03:59,460 --> 00:04:01,050

when I go out in the spring.

103

00:04:01,050 --> 00:04:03,360

There's nothing like, you know,
the most beautiful flower.

104

00:04:03,360 --> 00:04:04,890
Every flower is beautiful.

105

00:04:04,890 --> 00:04:07,620
It's very difficult to say
that this is good, this is bad.

106

00:04:07,620 --> 00:04:10,560
As long as there is a
pursuit in a sincere fashion,

107

00:04:10,560 --> 00:04:13,560
things will grow and
that's what is happening.

108

00:04:13,560 --> 00:04:15,030
- You said theoretical physics

109

00:04:15,030 --> 00:04:16,620
requires a lot of imagination,

110

00:04:16,620 --> 00:04:18,120
youthful imagination,

111

00:04:18,120 --> 00:04:20,580
but it also requires a lot of rigor

112

00:04:20,580 --> 00:04:23,130
and mathematics and experience.

113

00:04:23,130 --> 00:04:25,800
Is there a push and pull
there between your experience

114

00:04:25,800 --> 00:04:27,663
and their youthful imagination?

115

00:04:28,710 --> 00:04:30,420

- When you said rigor,

116

00:04:30,420 --> 00:04:32,400

in fact, recently I

was doing a conference,

117

00:04:32,400 --> 00:04:35,220

I was making a comment

about meaning of rigor.

118

00:04:35,220 --> 00:04:38,760

There is conceptual rigor, physical rigor,

119

00:04:38,760 --> 00:04:40,050

and mathematical rigor.

120

00:04:40,050 --> 00:04:41,581

My colleagues,

121

00:04:41,581 --> 00:04:42,750

some of them are very

rigorous in mathematics,

122

00:04:42,750 --> 00:04:44,790

they will make very sharp statements.

123

00:04:44,790 --> 00:04:46,500

There are people who will make very

124

00:04:46,500 --> 00:04:47,910

conceptually rigorous statements,

125

00:04:47,910 --> 00:04:49,440

mathematically may be very loose.

126

00:04:49,440 --> 00:04:51,750

So physics has all of them.

127

00:04:51,750 --> 00:04:55,050

Turns out, if you look at
the development of physics,

128

00:04:55,050 --> 00:04:57,360

conceptual rigor plays very important role

129

00:04:57,360 --> 00:05:01,080

and mathematical rigor or
using appropriate mathematics

130

00:05:01,080 --> 00:05:03,120

has been extremely important.

131

00:05:03,120 --> 00:05:05,190

One good example is Maxwell's equations.

132

00:05:05,190 --> 00:05:07,950

We had Faraday's law, Ampere's
law, Biot-Savart's law

133

00:05:07,950 --> 00:05:09,090

and then Gauss's law.

134

00:05:09,090 --> 00:05:11,610

And Maxwell had the genius
to put them together

135

00:05:11,610 --> 00:05:14,280

in the then new calculus into one form,

136

00:05:14,280 --> 00:05:16,770

it became Maxwell's equation
and changed the world.

137

00:05:16,770 --> 00:05:18,300

So mathematical rigor

138

00:05:18,300 --> 00:05:20,970

in the sense of using
appropriate mathematics

139

00:05:20,970 --> 00:05:24,180

is very important in physics.

140

00:05:24,180 --> 00:05:26,100

In terms of calculus, it
was available to Einstein,

141

00:05:26,100 --> 00:05:27,030

he used it.

142

00:05:27,030 --> 00:05:28,620

Hilbert space was available,

143

00:05:28,620 --> 00:05:31,050

people like (indistinct) and
Heisenberg, they used it.

144

00:05:31,050 --> 00:05:33,540

So using the right
mathematics in the right place

145

00:05:33,540 --> 00:05:34,710

is something very important.

146

00:05:34,710 --> 00:05:36,060

So it did not be rigorous

147

00:05:36,060 --> 00:05:38,700

in the sense of my
mathematical physics friends

148

00:05:38,700 --> 00:05:41,040

call it as rigorous, or like existence,

149

00:05:41,040 --> 00:05:43,590
showing that something
exists and is unique,

150

00:05:43,590 --> 00:05:45,000
that's the next level.

151

00:05:45,000 --> 00:05:47,610
What often worries, this is not the,

152

00:05:47,610 --> 00:05:49,470
they exists in their imagination,

153

00:05:49,470 --> 00:05:51,960
it exists in their mind,
they want to bring it out.

154

00:05:51,960 --> 00:05:54,270
Very often, you know intuitively

155

00:05:54,270 --> 00:05:55,620
what is going to be the result,

156

00:05:55,620 --> 00:05:57,300
so you strive towards it,

157

00:05:57,300 --> 00:05:59,277
you are guided by mathematics towards it

158

00:05:59,277 --> 00:06:01,680
and this very often happens.

159

00:06:01,680 --> 00:06:03,420
- In preparation for our conversation,

160

00:06:03,420 --> 00:06:06,510
you sent us a few articles
that you had written.

161

00:06:06,510 --> 00:06:08,610

And one thing that stood
out to me right away

162

00:06:08,610 --> 00:06:11,520

is that there were not
many mathematical equations

163

00:06:11,520 --> 00:06:12,480

in those papers.

164

00:06:12,480 --> 00:06:13,380

So this was actually something

165

00:06:13,380 --> 00:06:14,970

I already wanted to ask you about

166

00:06:14,970 --> 00:06:18,330

is if maybe this is something
that you tend to prefer

167

00:06:18,330 --> 00:06:21,630

or you find yourself more
drawn to a conceptual,

168

00:06:21,630 --> 00:06:23,403

rigorous way of thinking?

169

00:06:24,330 --> 00:06:25,894

- Yeah, because as I said,

170

00:06:25,894 --> 00:06:28,740

there are many ways of looking
at the structures in science.

171

00:06:28,740 --> 00:06:30,210

For example, one of my papers

172

00:06:30,210 --> 00:06:33,900

where I said that all
condensed matter phenomena

173

00:06:33,900 --> 00:06:36,450

mirror in biology in some way or other,

174

00:06:36,450 --> 00:06:39,360

simply because biology had
three billion years of time

175

00:06:39,360 --> 00:06:42,450

to think through and work
through, evolve and so on.

176

00:06:42,450 --> 00:06:44,610

So we are struggling
for the last 500 years

177

00:06:44,610 --> 00:06:46,410

in modern scientific methods,

178

00:06:46,410 --> 00:06:47,580

so you have discovered many things,

179

00:06:47,580 --> 00:06:49,350

but biology has found it.

180

00:06:49,350 --> 00:06:50,183

So I do not know

181

00:06:50,183 --> 00:06:53,310

what mathematics will
help me to think about it.

182

00:06:53,310 --> 00:06:55,560

To me, there are many conceptual issues

183

00:06:55,560 --> 00:06:56,400
which are very important,

184
00:06:56,400 --> 00:06:59,940
but of course, without
mathematics, they will stay there.

185
00:06:59,940 --> 00:07:02,460
You have to put it in
the form of mathematics,

186
00:07:02,460 --> 00:07:06,000
elementary, simple models and
if possible, new mathematics.

187
00:07:06,000 --> 00:07:06,930
That will take a long way.

188
00:07:06,930 --> 00:07:10,200
This combination of mathematics
and conceptualization

189
00:07:10,200 --> 00:07:12,810
is something very fundamental
in theoretical physics.

190
00:07:12,810 --> 00:07:14,640
I do not know if it is called rigorous,

191
00:07:14,640 --> 00:07:17,970
but the conceptualization
and using right mathematics,

192
00:07:17,970 --> 00:07:19,593
maybe inventing new mathematics.

193
00:07:20,490 --> 00:07:21,330
- That idea

194

00:07:21,330 --> 00:07:24,030
that you said everything
in condensed matter physics

195
00:07:24,030 --> 00:07:25,980
has a mirror in biology,

196
00:07:25,980 --> 00:07:27,450
I had never thought of it that way

197
00:07:27,450 --> 00:07:28,740
until you sent us this paper.

198
00:07:28,740 --> 00:07:31,440
And then thankfully for me,
that wasn't full of math

199
00:07:31,440 --> 00:07:32,850
and I was able to follow along.

200
00:07:32,850 --> 00:07:35,490
And it really hadn't
occurred to me that, yeah,

201
00:07:35,490 --> 00:07:38,280
evolution has had billions
of years of a head start

202
00:07:38,280 --> 00:07:39,330
on our physics.

203
00:07:39,330 --> 00:07:42,120
And it almost feels like
even though we're doing

204
00:07:42,120 --> 00:07:45,240
incredibly intricate and complex physics,

205
00:07:45,240 --> 00:07:46,710

we're still playing catch up

206

00:07:46,710 --> 00:07:48,840
to what nature has built already.

207

00:07:48,840 --> 00:07:51,120
How did you go down that line of thought?

208

00:07:51,120 --> 00:07:52,890
How did that first enter your?

209

00:07:52,890 --> 00:07:55,533
- Oh it goes to my teachers.

210

00:07:57,060 --> 00:08:00,720
I was fortunate enough to become a student

211

00:08:00,720 --> 00:08:02,730
at Indian Institute of
Science at Bangalore.

212

00:08:02,730 --> 00:08:06,090
I had a wonderful mentor
and teacher, Narendra Kumar.

213

00:08:06,090 --> 00:08:07,740
He was not my official guide.

214

00:08:07,740 --> 00:08:09,840
He started as an electrical engineer

215

00:08:09,840 --> 00:08:12,930
and he ended up as a maintenance engineer

216

00:08:12,930 --> 00:08:15,000
in a national chemical laboratory.

217

00:08:15,000 --> 00:08:17,220

Then there was a theoretical
physics was doing theoretical.

218

00:08:17,220 --> 00:08:20,430
We joined him and wrote a very quick PHD

219

00:08:20,430 --> 00:08:21,450
in theoretical physics,

220

00:08:21,450 --> 00:08:26,040
then he started working
on cosmology and biology.

221

00:08:26,040 --> 00:08:29,850
So he essentially showed
us that science is one.

222

00:08:29,850 --> 00:08:31,294
There is a web of science,

223

00:08:31,294 --> 00:08:32,700
every science is connected
with everything else.

224

00:08:32,700 --> 00:08:34,310
So he was a source of inspiration for us.

225

00:08:34,310 --> 00:08:38,477
So we had this inhibition
competition into biology and math

226

00:08:38,477 --> 00:08:41,160
and so I was removed by my teachers.

227

00:08:41,160 --> 00:08:43,590
The five years that during my PhD days,

228

00:08:43,590 --> 00:08:46,003
I was like a playboy,

you know, in the sense of

229

00:08:46,003 --> 00:08:48,480

never focused on my research,

230

00:08:48,480 --> 00:08:50,850

but seriously took other

things, other courses

231

00:08:50,850 --> 00:08:52,500

and enjoying it all the way

232

00:08:52,500 --> 00:08:54,080

because I had a good fellowship.

233

00:08:54,080 --> 00:08:56,010

- So you were earning a PhD in one subject

234

00:08:56,010 --> 00:08:57,850

and learning about all

the others at the same?

235

00:08:57,850 --> 00:08:59,590

- All the other things except for-

236

00:08:59,590 --> 00:09:00,423

- Except for what you

were supposed be doing?

237

00:09:00,423 --> 00:09:01,680

- To the extent my PhD paper,

238

00:09:01,680 --> 00:09:03,360

he's a great man,

239

00:09:03,360 --> 00:09:06,540

he's 95 now, he's still in Bangalore.

240

00:09:06,540 --> 00:09:09,720
So he was worried, he let me loose,

241
00:09:09,720 --> 00:09:11,100
he gave me full independence,

242
00:09:11,100 --> 00:09:13,170
but he thought at some point
I should write my thesis.

243
00:09:13,170 --> 00:09:14,527
So at the end of three years he asked me,

244
00:09:14,527 --> 00:09:15,988
"Why don't you write your thesis?"

245
00:09:15,988 --> 00:09:17,520
I said, "I'm not satisfied."

246
00:09:17,520 --> 00:09:20,220
So he waited for six more
months, asked the same question.

247
00:09:20,220 --> 00:09:24,240
Then after one year, that
means at the end of four years.

248
00:09:24,240 --> 00:09:26,040
I said, "Professor, I'm not satisfied,

249
00:09:26,040 --> 00:09:27,720
I want to do some more work."

250
00:09:27,720 --> 00:09:29,730
Then, apparently he thought in his mind,

251
00:09:29,730 --> 00:09:33,183
this fellow is gone case,
he will never get a PhD.

252

00:09:36,180 --> 00:09:37,200

- He'd given up on you?

253

00:09:37,200 --> 00:09:38,760

- No, he didn't do,

254

00:09:38,760 --> 00:09:41,100

he couldn't do anything
because he was a kind man,

255

00:09:41,100 --> 00:09:44,940

so I was doing enjoying physics.

256

00:09:44,940 --> 00:09:47,130

Then, you know, I do not
know if I can say this,

257

00:09:47,130 --> 00:09:49,590

in India, marriages are
fixed, are arranged,

258

00:09:49,590 --> 00:09:51,510

so marriage was arranged.

259

00:09:51,510 --> 00:09:55,050

So then I thought that before
I submit myself to some lady,

260

00:09:55,050 --> 00:09:56,493

I should submit my thesis.

261

00:09:57,990 --> 00:10:00,480

So literally in three
months I wrote my thesis

262

00:10:00,480 --> 00:10:03,270

in preparation to get married.

263

00:10:03,270 --> 00:10:04,653

- I've never heard,

264

00:10:04,653 --> 00:10:07,720

no one has ever told us I got
my PhD so I could get married.

265

00:10:07,720 --> 00:10:09,359

You're the first one to mention that.

266

00:10:09,359 --> 00:10:10,440

- No, it's that way

267

00:10:10,440 --> 00:10:12,510

because I thought if I get married,

268

00:10:12,510 --> 00:10:13,770

then there'll be other competitions,

269

00:10:13,770 --> 00:10:15,810

I will have no time to finish my PhD.

270

00:10:15,810 --> 00:10:17,070

And my guide was very good.

271

00:10:17,070 --> 00:10:18,840

He grabbed this opportunity

272

00:10:18,840 --> 00:10:21,120

and corrected my entire
thesis in three days

273

00:10:21,120 --> 00:10:23,880

and gave it back to me so that
I can type the manuscript.

274

00:10:23,880 --> 00:10:25,560

So he was waiting for an opportunity.

275

00:10:25,560 --> 00:10:27,750

So I had good people in all along.

276

00:10:27,750 --> 00:10:30,420

- When we first sat down to chat with you,

277

00:10:30,420 --> 00:10:33,540

we got speaking right away and
the conversation was flowing

278

00:10:33,540 --> 00:10:36,780

and we got talking about
biology and quantum biology

279

00:10:36,780 --> 00:10:37,613

and I said to you,

280

00:10:37,613 --> 00:10:40,740

"Is this your specialty,
your line of research?"

281

00:10:40,740 --> 00:10:42,600

And you said, "Oh no, no,
that's not my bread and butter.

282

00:10:42,600 --> 00:10:44,757

That's something else I do."

283

00:10:44,757 --> 00:10:48,330

And it amazed me that your
sort of professional focus

284

00:10:48,330 --> 00:10:50,550

has been largely condensed matter and-

285

00:10:50,550 --> 00:10:52,230

- Strongly correlated electron system.

286

00:10:52,230 --> 00:10:54,658

- Yeah, super conductivity questions,

287

00:10:54,658 --> 00:10:57,270

but your interests are so broad.

288

00:10:57,270 --> 00:10:58,920

And so we continued carrying on

289

00:10:58,920 --> 00:11:02,730

about this subject of quantum biology.

290

00:11:02,730 --> 00:11:06,090

Has it been that way your whole
life, even prior to the PhD,

291

00:11:06,090 --> 00:11:10,113

where you're just interested
in a wide range of subjects?

292

00:11:10,980 --> 00:11:13,200

- No, it's very interesting question.

293

00:11:13,200 --> 00:11:16,650

Prior to PhD, I was in a
good college in Madurai,

294

00:11:16,650 --> 00:11:19,560

where I had a masters, very good teachers.

295

00:11:19,560 --> 00:11:20,970

So I took the subject seriously

296

00:11:20,970 --> 00:11:23,100

and I learned whatever I was learning.

297

00:11:23,100 --> 00:11:26,670

I had no particular fascination

about quantum mechanics

298

00:11:26,670 --> 00:11:28,710

or mathematical physics.

299

00:11:28,710 --> 00:11:31,170

So I had no vision what to do.

300

00:11:31,170 --> 00:11:33,510

In fact, it's after coming to Bangalore,

301

00:11:33,510 --> 00:11:35,160

my ideas got sharpened.

302

00:11:35,160 --> 00:11:38,237

In fact, that's also an
accident coming to Bangalore.

303

00:11:38,237 --> 00:11:39,720

I was about to finish my first year

304

00:11:39,720 --> 00:11:41,490

so I had no idea what I will do.

305

00:11:41,490 --> 00:11:45,540

So one day my professor, Richard
Pieris, he's a great man,

306

00:11:45,540 --> 00:11:46,890

it was a missionary college,

307

00:11:46,890 --> 00:11:48,450

Madurai American College.

308

00:11:48,450 --> 00:11:50,760

Missionaries used to
invite like scientists

309

00:11:50,760 --> 00:11:52,530
to spend one year around sabbatical.

310
00:11:52,530 --> 00:11:56,220
So Richard Pieris was a
scientist at Bell Laboratories,

311
00:11:56,220 --> 00:12:00,180
came to Chennai and Madurai
for one year to teach physics.

312
00:12:00,180 --> 00:12:01,440
Then he fell in love with Madurai

313
00:12:01,440 --> 00:12:03,690
and stayed there for 35 years.

314
00:12:03,690 --> 00:12:05,100
So that was Richard Pieris.

315
00:12:05,100 --> 00:12:08,994
He started postgraduate
department of physics at Madurai

316
00:12:08,994 --> 00:12:11,250
and then he was my professor,
very inspiring professor.

317
00:12:11,250 --> 00:12:13,980
So one day he asked me,
"What are your plans?"

318
00:12:13,980 --> 00:12:15,330
Honestly I had no plans.

319
00:12:15,330 --> 00:12:18,420
So I told him, "I may become
a tutor in a college."

320

00:12:18,420 --> 00:12:19,567
It's like a junior lecturer.

321
00:12:19,567 --> 00:12:21,343
"Suppose you don't get
it, what will you do?"

322
00:12:21,343 --> 00:12:23,310
I said, "I may become a research scholar

323
00:12:23,310 --> 00:12:25,770
in Madurai University because
I saw an advertisement

324
00:12:25,770 --> 00:12:28,537
they say about some fellowship
so I may go for that."

325
00:12:28,537 --> 00:12:30,360
"Suppose you don't get
it, what will you do?"

326
00:12:30,360 --> 00:12:31,287
I had no idea.

327
00:12:31,287 --> 00:12:32,120
And he asked me,

328
00:12:32,120 --> 00:12:34,230
"Do you know about Indian
Institute of Science at Bangalore?"

329
00:12:34,230 --> 00:12:35,070
Have you heard about it?"

330
00:12:35,070 --> 00:12:35,903
I said, "No."

331
00:12:35,903 --> 00:12:37,860

"So you have some motivation,

332

00:12:37,860 --> 00:12:39,270

you have some energy,

333

00:12:39,270 --> 00:12:41,610

so why don't you apply for a PhD program?"

334

00:12:41,610 --> 00:12:42,630

So that's how I ended up

335

00:12:42,630 --> 00:12:44,280

in Indian Institute of Science Bangalore.

336

00:12:44,280 --> 00:12:45,120

The time took me,

337

00:12:45,120 --> 00:12:47,550

I never planned for
anything in my whole life.

338

00:12:47,550 --> 00:12:49,080

I'm carried by time.

339

00:12:49,080 --> 00:12:50,983

I was not thinking about job at all,

340

00:12:50,983 --> 00:12:53,100

I was enjoying whatever I was doing.

341

00:12:53,100 --> 00:12:55,470

Physics department won't
invite me for an interview

342

00:12:55,470 --> 00:12:56,970

'cause they had a way of screening.

343

00:12:56,970 --> 00:13:01,350

My marks at junior college
level was not satisfactory

344

00:13:01,350 --> 00:13:03,480
so I was screened out on that basis.

345

00:13:03,480 --> 00:13:05,820
Then mathematics department selected me.

346

00:13:05,820 --> 00:13:07,260
They didn't have too many applications

347

00:13:07,260 --> 00:13:08,820
so I got in.

348

00:13:08,820 --> 00:13:09,950
The head department pass away,

349

00:13:09,950 --> 00:13:12,420
so the director of the
institute, Satish Dhawan.

350

00:13:12,420 --> 00:13:14,732
So he was sitting in the entry committee

351

00:13:14,732 --> 00:13:16,890
and I answered questions
so I was selected.

352

00:13:16,890 --> 00:13:20,040
After four months, I was
fascinated by a course

353

00:13:20,040 --> 00:13:22,470
on quantum body theory
given by Professor N. Kumar

354

00:13:22,470 --> 00:13:24,000
whom I was mentioning.

355

00:13:24,000 --> 00:13:25,590
So I was so fascinated by it,

356

00:13:25,590 --> 00:13:28,350
I wanted to change to physics
department if possible.

357

00:13:28,350 --> 00:13:30,840
So I directly went to
the head of department

358

00:13:30,840 --> 00:13:32,340
who was the director.

359

00:13:32,340 --> 00:13:34,087
So he called the department,

360

00:13:34,087 --> 00:13:35,970
"Baskaran is interested
in shifting, will you?"

361

00:13:35,970 --> 00:13:37,410
He said, "No, no, we won't call him

362

00:13:37,410 --> 00:13:39,300
because he was not even
called for interview.

363

00:13:39,300 --> 00:13:41,070
We have different standards."

364

00:13:41,070 --> 00:13:41,903
So he said,

365

00:13:41,903 --> 00:13:43,260
"As a director, I'm requesting you,

366

00:13:43,260 --> 00:13:45,240
please have a second interview for him."

367
00:13:45,240 --> 00:13:46,860
So they had a second interview for me

368
00:13:46,860 --> 00:13:48,420
and then I was selected.

369
00:13:48,420 --> 00:13:49,980
And that meant that Satish Dhawan,

370
00:13:49,980 --> 00:13:52,800
he's the father of Indian Space Mission.

371
00:13:52,800 --> 00:13:55,500
He was a very effective
man, very selfless.

372
00:13:55,500 --> 00:13:56,940
He became the chairman

373
00:13:56,940 --> 00:13:59,220
of Indian Space Research Organization.

374
00:13:59,220 --> 00:14:03,030
And in India, among the various
ministries, organizations,

375
00:14:03,030 --> 00:14:04,530
space research is one of the best.

376
00:14:04,530 --> 00:14:06,243
It's because of Satish Dhawan.

377
00:14:07,290 --> 00:14:08,610
- You know, I love this story

378

00:14:08,610 --> 00:14:10,650
that you know, some departments

379
00:14:10,650 --> 00:14:13,470
maybe overlooked you at
first just because of marks.

380
00:14:13,470 --> 00:14:16,260
and I think that we tend to look at marks

381
00:14:16,260 --> 00:14:18,360
as the first thing when
selecting students,

382
00:14:18,360 --> 00:14:20,730
but I'm not sure that it's
really the best metric.

383
00:14:20,730 --> 00:14:21,930
So what do you think

384
00:14:21,930 --> 00:14:23,460
we really should be looking for instead?

385
00:14:23,460 --> 00:14:24,360
- Yeah, that's a very good question.

386
00:14:24,360 --> 00:14:27,690
So as much as possible, one
should interact with students.

387
00:14:27,690 --> 00:14:29,010
In our own institute,

388
00:14:29,010 --> 00:14:31,170
we often don't give too
much importance to marks.

389
00:14:31,170 --> 00:14:32,130

We are very liberated

390

00:14:32,130 --> 00:14:34,320
in terms of getting
students for interview.

391

00:14:34,320 --> 00:14:36,660
There will be students
with very low marks,

392

00:14:36,660 --> 00:14:39,960
but you can see their
talents very clearly.

393

00:14:39,960 --> 00:14:41,940
Of course, you know
it's very difficult to,

394

00:14:41,940 --> 00:14:44,640
when you have a big organization,
there are rules and so on,

395

00:14:44,640 --> 00:14:47,130
it's very difficult to overcome this.

396

00:14:47,130 --> 00:14:49,200
But as much as possible,
one should talk to people.

397

00:14:49,200 --> 00:14:52,680
In fact, I know of some
universities in India

398

00:14:52,680 --> 00:14:53,790
where they do this,

399

00:14:53,790 --> 00:14:55,470
they invite students

400

00:14:55,470 --> 00:14:58,470
and then they have about
50 students in a group

401
00:14:58,470 --> 00:14:59,850
and they go with the professors,

402
00:14:59,850 --> 00:15:01,320
they spend half a day together.

403
00:15:01,320 --> 00:15:02,670
That makes a difference

404
00:15:02,670 --> 00:15:05,550
other than looking at the
application and marks and so on.

405
00:15:05,550 --> 00:15:07,170
One pyramid and scholars international,

406
00:15:07,170 --> 00:15:09,000
I know that they don't depend on mark,

407
00:15:09,000 --> 00:15:10,860
they depend on recommendation letters,

408
00:15:10,860 --> 00:15:13,560
which is another very important thing.

409
00:15:13,560 --> 00:15:16,860
- And if you were 18, 19 years old now,

410
00:15:16,860 --> 00:15:19,260
would you follow a similar
path as you've taken before

411
00:15:19,260 --> 00:15:22,200
or do you have advice for people
who are just starting out?

412

00:15:22,200 --> 00:15:24,600

- I tell them that just
follow your passion

413

00:15:24,600 --> 00:15:26,880

because these days, you
can excel in anything.

414

00:15:26,880 --> 00:15:28,150

The world is different from my days.

415

00:15:28,150 --> 00:15:31,710

There are people who I want
to become only a doctor,

416

00:15:31,710 --> 00:15:32,760

nothing else.

417

00:15:32,760 --> 00:15:35,220

But then on the other hand, you
don't know your own talents.

418

00:15:35,220 --> 00:15:38,970

Your own talents may be in
painting, you are fascinated,

419

00:15:38,970 --> 00:15:41,100

so give it a chance.

420

00:15:41,100 --> 00:15:43,530

- It seems that you've
benefited in your life

421

00:15:43,530 --> 00:15:45,570

from mentors and teachers

422

00:15:45,570 --> 00:15:48,272

who gave you that kind of encouragement,

423

00:15:48,272 --> 00:15:50,430
who gave you the leeway to explore.

424

00:15:50,430 --> 00:15:53,207
- Exactly, I should, very
important to mention two teachers.

425

00:15:53,207 --> 00:15:55,590
When I was studying my 10th standard,

426

00:15:55,590 --> 00:15:58,667
I was regularly failing
in my mathematics exam

427

00:15:58,667 --> 00:15:59,500
and I used to be a good student,

428

00:15:59,500 --> 00:16:00,333
I was not a naughty student,

429

00:16:00,333 --> 00:16:03,300
there were 52 students
in the class, 52, 55,

430

00:16:03,300 --> 00:16:04,140
so it was a big class.

431

00:16:04,140 --> 00:16:07,020
So I was always sitting in
the front and very attentive.

432

00:16:07,020 --> 00:16:08,280
He said that, "You seem to be attentive,

433

00:16:08,280 --> 00:16:09,457
why are you failing at math?"

434

00:16:09,457 --> 00:16:12,300

"Sir, I understand
whatever you are saying.

435

00:16:12,300 --> 00:16:14,970

I revised the subject
one day before the exam.

436

00:16:14,970 --> 00:16:16,560

I go and sit in the exam hall,

437

00:16:16,560 --> 00:16:19,110

I'm not able to answer any question."

438

00:16:19,110 --> 00:16:21,120

He said, "Do you do homework
and work out problems?"

439

00:16:21,120 --> 00:16:23,755

I said, "No sir, I help my mother."

440

00:16:23,755 --> 00:16:26,670

He said, "You should work
out mathematical problems.

441

00:16:26,670 --> 00:16:29,040

Mathematics comes only by working out."

442

00:16:29,040 --> 00:16:31,860

So he taught me how to do
homework and work on problems

443

00:16:31,860 --> 00:16:33,420

because we had nothing like a homework,

444

00:16:33,420 --> 00:16:34,830

there is no compulsion.

445

00:16:34,830 --> 00:16:36,720

So he taught me how to
record the problems.

446

00:16:36,720 --> 00:16:38,190
So from that period onwards,

447

00:16:38,190 --> 00:16:40,740
I started getting better marks, past mark.

448

00:16:40,740 --> 00:16:44,010
- He taught you how to
reason through the problems,

449

00:16:44,010 --> 00:16:45,570
how to figure them out yourself

450

00:16:45,570 --> 00:16:48,480
or was it that you were not understanding

451

00:16:48,480 --> 00:16:50,250
how he was teaching them or you weren't

452

00:16:50,250 --> 00:16:51,083
ingesting it?
- No, no, no,

453

00:16:51,083 --> 00:16:52,050
I was understanding

454

00:16:52,050 --> 00:16:55,200
but I simply had no time to do my homework

455

00:16:55,200 --> 00:16:57,180
'cause once I go home I started playing

456

00:16:57,180 --> 00:17:00,210
'cause I am from hardworking
parents, nine children

457
00:17:00,210 --> 00:17:02,640
and I had many, many friends.

458
00:17:02,640 --> 00:17:05,400
We used to play and there
was a public park nearby,

459
00:17:05,400 --> 00:17:06,233
there's a gym,

460
00:17:06,233 --> 00:17:07,800
I used to be a street
gymnast kind of thing,

461
00:17:07,800 --> 00:17:09,420
you know, do all kinds of things there.

462
00:17:09,420 --> 00:17:12,180
My parents were happy as long

463
00:17:12,180 --> 00:17:15,270
as I am not naughty and I'm not rowdy.

464
00:17:15,270 --> 00:17:18,270
So there was no insistence on
sitting at home and studying.

465
00:17:18,270 --> 00:17:21,690
Like in my one family, when
I completed eighth grade,

466
00:17:21,690 --> 00:17:23,190
that's an interesting point,

467
00:17:23,190 --> 00:17:25,740
in which if you are
studying, you can study.

468

00:17:25,740 --> 00:17:27,270
Otherwise, you go for a job.

469
00:17:27,270 --> 00:17:31,260
So many of my relatives came
and wanted to take me away for,

470
00:17:31,260 --> 00:17:33,330
to become their apprentice in a shop.

471
00:17:33,330 --> 00:17:35,490
And my mom and dad, they
were very enlightened.

472
00:17:35,490 --> 00:17:40,410
My dad was a very hard worker
and he has not studied,

473
00:17:40,410 --> 00:17:42,570
he has studied until second grade.

474
00:17:42,570 --> 00:17:43,830
He was a socialist, you know,

475
00:17:43,830 --> 00:17:45,870
he believed in socialism

476
00:17:45,870 --> 00:17:48,180
and money should be spent for everybody.

477
00:17:48,180 --> 00:17:50,370
Also, he realized the
importance of education.

478
00:17:50,370 --> 00:17:51,203
So he said,

479
00:17:51,203 --> 00:17:53,880
since I'm studying without

failing my annual exam,

480

00:17:53,880 --> 00:17:54,810
he said, "Let him continue."

481

00:17:54,810 --> 00:17:57,930
My mom also, she had
completed eighth grade,

482

00:17:57,930 --> 00:18:00,660
which is a big step in her days.

483

00:18:00,660 --> 00:18:02,520
She said, "This boy should continue."

484

00:18:02,520 --> 00:18:06,030
So none of my brothers
went beyond high school.

485

00:18:06,030 --> 00:18:09,090
And the thanks to great
politician by the name Kamaraj,

486

00:18:09,090 --> 00:18:12,090
he had just introduced free
education for poor children.

487

00:18:12,090 --> 00:18:13,380
Otherwise, it would have been impossible

488

00:18:13,380 --> 00:18:14,700
for them to pay my fees.

489

00:18:14,700 --> 00:18:17,151
- So your education was government?

490

00:18:17,151 --> 00:18:18,600
- Government, exactly until my,

491

00:18:18,600 --> 00:18:20,730
nominal, half a dollar

492

00:18:20,730 --> 00:18:23,310
or even much less in Indian, two Rupees

493

00:18:23,310 --> 00:18:25,230
That's why I was able to study

494

00:18:25,230 --> 00:18:27,480
and I was not a problematic child.

495

00:18:27,480 --> 00:18:30,330
I was good at hands, I
can make things, break it.

496

00:18:30,330 --> 00:18:31,890
So I wanted to become an engineer.

497

00:18:31,890 --> 00:18:34,320
But when I finished my
school and enter college,

498

00:18:34,320 --> 00:18:37,200
you need some mark, some minimum mark.

499

00:18:37,200 --> 00:18:38,670
I did not have a minimum mark

500

00:18:38,670 --> 00:18:40,200
so I could not become an engineer.

501

00:18:40,200 --> 00:18:43,470
My friend said take chemistry
or zoology or this and that.

502

00:18:43,470 --> 00:18:44,580
I had no clear idea.

503

00:18:44,580 --> 00:18:46,800

Then one day I was going
to the principal's office

504

00:18:46,800 --> 00:18:48,450

with the application form

505

00:18:48,450 --> 00:18:52,080

in which I had left the group
without mentioning what it is.

506

00:18:52,080 --> 00:18:54,120

So my friend came out
of principal's office.

507

00:18:54,120 --> 00:18:56,550

I asked him, "Christian,
what subject are you taking?"

508

00:18:56,550 --> 00:18:57,383

He said, "Physics."

509

00:18:57,383 --> 00:18:58,216

I put physics.

510

00:18:58,216 --> 00:19:00,270

That was my how I entered into physics.

511

00:19:00,270 --> 00:19:01,140

- That's pretty amazing

512

00:19:01,140 --> 00:19:04,410

from a family where most people
don't go past eighth grade

513

00:19:04,410 --> 00:19:07,740

to you eventually earning
a PhD and then working

514
00:19:07,740 --> 00:19:11,021
as a physicist your whole life.

515
00:19:11,021 --> 00:19:13,200
It's a different path that I
assume most of your friends-

516
00:19:13,200 --> 00:19:15,327
- Oh yeah, yeah, totally different path,

517
00:19:15,327 --> 00:19:18,690
and at every stage I can
say somebody lifted me up

518
00:19:18,690 --> 00:19:21,420
and put me up, that's something.

519
00:19:21,420 --> 00:19:23,700
Then, as I tell, in 10th
standard, my maths teacher,

520
00:19:23,700 --> 00:19:26,940
and 11th standard, my English teacher.

521
00:19:26,940 --> 00:19:28,680
I was also failing in English.

522
00:19:28,680 --> 00:19:31,140
My English teacher,
Reverend Father, KSR Antham

523
00:19:31,140 --> 00:19:33,677
he was a great man, but he
was a terror to the students,

524
00:19:33,677 --> 00:19:35,490
he was very strict guy.

525

00:19:35,490 --> 00:19:37,030

One day, he was reading the marks

526

00:19:37,030 --> 00:19:39,180

and I got 32 marks in English.

527

00:19:39,180 --> 00:19:41,160

35 is the pass mark out of hundred.

528

00:19:41,160 --> 00:19:42,600

So he asked me, "Why are you failing?"

529

00:19:42,600 --> 00:19:44,910

I said, "Father, I can't memorize things."

530

00:19:44,910 --> 00:19:46,380

He said, "No, no, you should not memorize,

531

00:19:46,380 --> 00:19:47,940

you should understand."

532

00:19:47,940 --> 00:19:49,200

So he told me how to understand.

533

00:19:49,200 --> 00:19:51,120

He asked me to buy a dictionary

534

00:19:51,120 --> 00:19:54,120

and draw line under a word
that you don't understand

535

00:19:54,120 --> 00:19:56,220

and then write the meaning in Tamil.

536

00:19:56,220 --> 00:19:59,820

Then he said, "Read each
lesson 10 times slowly

537
00:19:59,820 --> 00:20:01,950
and something will sink into your mind

538
00:20:01,950 --> 00:20:04,140
and go and write whatever
comes out of your mind,

539
00:20:04,140 --> 00:20:05,220
you'll pass."

540
00:20:05,220 --> 00:20:07,050
And then I started passing the exam.

541
00:20:07,050 --> 00:20:09,600
So that was a very important step for me.

542
00:20:09,600 --> 00:20:11,040
- And then at some point I guess

543
00:20:11,040 --> 00:20:13,860
you had to even further specialize

544
00:20:13,860 --> 00:20:16,470
into strongly correlated electron systems.

545
00:20:16,470 --> 00:20:18,840
How did that choice happen?

546
00:20:18,840 --> 00:20:20,250
- My professor, N. Kumar,

547
00:20:20,250 --> 00:20:23,520
he used to go to ICTP, International
Center for Theoretical Physics,

548
00:20:23,520 --> 00:20:25,710
every time he'll come back
and tell what is exciting.

549

00:20:25,710 --> 00:20:26,910

So he gave a set of lectures

550

00:20:26,910 --> 00:20:29,070

on strongly correlated electron system

551

00:20:29,070 --> 00:20:31,170

and modern developments in the field.

552

00:20:31,170 --> 00:20:32,003

- Just to stop,

553

00:20:32,003 --> 00:20:34,380

ICTP, that's in Trieste, Italy,

554

00:20:34,380 --> 00:20:37,740

that's the International
Center for Theoretical Physics?

555

00:20:37,740 --> 00:20:40,320

- My professor was a
regular visitor there.

556

00:20:40,320 --> 00:20:41,850

He was an young professor

557

00:20:41,850 --> 00:20:44,850

and then he also started working on some,

558

00:20:44,850 --> 00:20:48,750

we had an outstanding
visitor from Bell Labs

559

00:20:48,750 --> 00:20:51,660

by name Jay Ramen and he
gave some series of lectures

560

00:20:51,660 --> 00:20:53,460
on some outstanding phenomena

561
00:20:53,460 --> 00:20:56,460
and strongly correlated
system and heavy fermions.

562
00:20:56,460 --> 00:20:57,480
So I was exposed to that.

563
00:20:57,480 --> 00:20:59,280
That was not part of my PhD thesis.

564
00:20:59,280 --> 00:21:00,600
And it became very clear,

565
00:21:00,600 --> 00:21:03,000
strongly correlated
electron systems are very,

566
00:21:03,000 --> 00:21:04,560
offer many challenges.

567
00:21:04,560 --> 00:21:07,710
Again, I have to tell,
it's very important.

568
00:21:07,710 --> 00:21:10,800
I was fortunate to meet
professor at Bangalore

569
00:21:10,800 --> 00:21:12,360
by name S.K. Rangarajan.

570
00:21:12,360 --> 00:21:13,880
He was a phenomena himself.

571
00:21:13,880 --> 00:21:15,840
He was only an undergraduate,

572

00:21:15,840 --> 00:21:18,960

he became a senior
professor, he had no PhD,

573

00:21:18,960 --> 00:21:20,490

because of his talent.

574

00:21:20,490 --> 00:21:21,960

So he found us students

575

00:21:21,960 --> 00:21:24,120

with Department of Theoretical Physics.

576

00:21:24,120 --> 00:21:26,857

So he collected us one day.

577

00:21:26,857 --> 00:21:28,530

"You are all very motivated and so on,

578

00:21:28,530 --> 00:21:30,180

but the way that you are
doing theoretical physics

579

00:21:30,180 --> 00:21:31,020

is not correct.

580

00:21:31,020 --> 00:21:33,150

So you should have group discussion.

581

00:21:33,150 --> 00:21:36,090

So he just collected us
together and put us together

582

00:21:36,090 --> 00:21:37,620

and he would invite us to his house,

583

00:21:37,620 --> 00:21:39,420

which is not far from the institute,

584

00:21:39,420 --> 00:21:42,060
so we'll go at eight o'clock
and sit for two, three hours.

585

00:21:42,060 --> 00:21:44,400
And he said the idea
is not to read papers.

586

00:21:44,400 --> 00:21:45,447
He made it very clear.

587

00:21:45,447 --> 00:21:48,720
The idea is to go deep
into classic papers.

588

00:21:48,720 --> 00:21:51,420
And one of the classic papers
was by Philip W. Anderson,

589

00:21:51,420 --> 00:21:52,590
the great Nobel Laureate

590

00:21:52,590 --> 00:21:54,300
So I was introduced to Anderson's paper

591

00:21:54,300 --> 00:21:56,280
in Rangarajan's house

592

00:21:56,280 --> 00:21:57,660
through discussion.

593

00:21:57,660 --> 00:21:58,920
So that's how I was exposed

594

00:21:58,920 --> 00:22:01,530
to this quantum many-body
systems and so on.

595

00:22:01,530 --> 00:22:04,110

P.W. Anderson became my hero.

596

00:22:04,110 --> 00:22:05,610

It was very clear he's outstanding

597

00:22:05,610 --> 00:22:07,560

the way that he was
doing things and so on.

598

00:22:07,560 --> 00:22:10,800

So it's in that background I
grew up and wrote a thesis.

599

00:22:10,800 --> 00:22:12,930

- And he eventually
became not just your hero

600

00:22:12,930 --> 00:22:15,000

but your longtime
collaborator, is that right?

601

00:22:15,000 --> 00:22:17,000

- Yeah, that was thanks to ICTP.

602

00:22:17,000 --> 00:22:18,510

So I submitted my thesis.

603

00:22:18,510 --> 00:22:20,370

The Institute of Mathematical Sciences

604

00:22:20,370 --> 00:22:21,900

wanted to give me a job,

605

00:22:21,900 --> 00:22:24,660

but they could not because
I had no publications.

606
00:22:24,660 --> 00:22:26,940
So they gave me a nice fellowship.

607
00:22:26,940 --> 00:22:28,320
I got married already.

608
00:22:28,320 --> 00:22:32,190
So then I saw this advertisement
by Winter College at ICTP

609
00:22:32,190 --> 00:22:33,450
so I applied for it.

610
00:22:33,450 --> 00:22:35,530
A friend of mine helped me
to get travel fellowship

611
00:22:35,530 --> 00:22:36,757
and I went there.

612
00:22:36,757 --> 00:22:39,300
So there, it was again in a place,

613
00:22:39,300 --> 00:22:41,610
an eclectic place, I
listened to all talks.

614
00:22:41,610 --> 00:22:43,620
My mentors there liked it

615
00:22:43,620 --> 00:22:46,692
because many people came down
there to just write papers.

616
00:22:46,692 --> 00:22:47,670
I never wrote any papers.

617
00:22:47,670 --> 00:22:49,380

I was interacting with people,

618

00:22:49,380 --> 00:22:50,520
so they were very happy with me,

619

00:22:50,520 --> 00:22:52,740
they made me an associate and so on.

620

00:22:52,740 --> 00:22:56,220
So I was going there every
year since '76 for three months

621

00:22:56,220 --> 00:22:57,750
participating actively.

622

00:22:57,750 --> 00:23:01,170
And in fact they were so nice,

623

00:23:01,170 --> 00:23:02,520
in the second year they asked me

624

00:23:02,520 --> 00:23:04,590
to be responsible for a conference.

625

00:23:04,590 --> 00:23:06,420
They asked me to collect the
best people in that field

626

00:23:06,420 --> 00:23:08,284
and organize a conference, which I did,

627

00:23:08,284 --> 00:23:10,950
and it allowed me to interact,
I met many great people.

628

00:23:10,950 --> 00:23:13,500
- You mentioned that a friend
arranged a travel fellowship.

629

00:23:13,500 --> 00:23:15,510
Would you have been able to go,

630

00:23:15,510 --> 00:23:19,350
had that travel reimbursement
not been possible?

631

00:23:19,350 --> 00:23:20,370
- No, it would not have been possible

632

00:23:20,370 --> 00:23:21,780
because it's a huge amount

633

00:23:21,780 --> 00:23:24,690
in Indian's salary and my background.

634

00:23:24,690 --> 00:23:26,962
See this friend's name
is Subbiah Arunachalam.

635

00:23:26,962 --> 00:23:29,365
He's a champion of open access.

636

00:23:29,365 --> 00:23:32,160
He's 80 plus, he's still
very active in India.

637

00:23:32,160 --> 00:23:33,690
So this guy and me met,

638

00:23:33,690 --> 00:23:36,660
we were together at
Indian Science Bangalore.

639

00:23:36,660 --> 00:23:39,570
He was four years senior
to me, four or five years.

640

00:23:39,570 --> 00:23:44,220
But still, he came for a PhD
much later so we were friends.

641
00:23:44,220 --> 00:23:45,390
So I wrote to to him saying

642
00:23:45,390 --> 00:23:47,700
that I am applying for a travel fellowship

643
00:23:47,700 --> 00:23:49,140
and you know there are bureaucracy

644
00:23:49,140 --> 00:23:51,720
and there are ways there
may be delay and so on.

645
00:23:51,720 --> 00:23:53,490
He immediately took my application

646
00:23:53,490 --> 00:23:56,010
and went around the offices in Delhi

647
00:23:56,010 --> 00:23:58,170
and said that this boy should be supported

648
00:23:58,170 --> 00:23:59,160
'cause he is very serious.

649
00:23:59,160 --> 00:24:00,920
So that's how I got my travel fellowship.

650
00:24:00,920 --> 00:24:02,280
Arunachalam is that.

651
00:24:02,280 --> 00:24:05,220
He's a kind of angel, you
know, he helps everybody.

652

00:24:05,220 --> 00:24:06,840

Whenever he gets a
chance, he'll get people.

653

00:24:06,840 --> 00:24:09,197

He's a very selfless person.

654

00:24:10,200 --> 00:24:12,120

- So I think what we're
talking about right now

655

00:24:12,120 --> 00:24:14,610

relates a little bit to
the talk that you gave here

656

00:24:14,610 --> 00:24:16,350

at Perimeter Institute on Friday.

657

00:24:16,350 --> 00:24:17,580

Could you tell us a little bit

658

00:24:17,580 --> 00:24:20,100

about the subject of this talk you gave?

659

00:24:20,100 --> 00:24:21,413

- It was Abdus Salam

660

00:24:21,413 --> 00:24:23,881

and the International Center
for Theoretical Physics,

661

00:24:23,881 --> 00:24:26,010

Abdus Salam at ICTP.

662

00:24:26,010 --> 00:24:28,350

Abdus Salam, as many of you know,

663

00:24:28,350 --> 00:24:29,910

is a very famous Nobel Laureate.

664

00:24:29,910 --> 00:24:33,150

He got his Nobel Prize along with Glashow

665

00:24:33,150 --> 00:24:35,730

for standard model, grand unification

666

00:24:35,730 --> 00:24:38,220

of strong, weak and
electromagnetic interaction.

667

00:24:38,220 --> 00:24:40,290

In addition to being a
great theoretical physicist,

668

00:24:40,290 --> 00:24:42,660

he was a remarkable human being

669

00:24:42,660 --> 00:24:46,590

who was passionate about
wellbeing of common people

670

00:24:46,590 --> 00:24:47,760

all over the world.

671

00:24:47,760 --> 00:24:49,950

So in particular, he
said that poor countries

672

00:24:49,950 --> 00:24:53,160

should make use of science
in their development

673

00:24:53,160 --> 00:24:54,690

'cause science and technology

674

00:24:54,690 --> 00:24:58,110

has been helping humanity

enormously over the years.

675

00:24:58,110 --> 00:25:00,000

So we should not lose that talent,

676

00:25:00,000 --> 00:25:02,520

we should nurture it in
every developing countries.

677

00:25:02,520 --> 00:25:04,170

So he himself was an example,

678

00:25:04,170 --> 00:25:06,840

you know, he did a good
theoretical physics PhD

679

00:25:06,840 --> 00:25:09,780

at Cambridge, Princeton and
he went back, was isolated.

680

00:25:09,780 --> 00:25:11,580

So he wanted to move that isolation.

681

00:25:11,580 --> 00:25:14,760

So one way is to build an
institute, international center,

682

00:25:14,760 --> 00:25:17,190

where isolated people
are brought together,

683

00:25:17,190 --> 00:25:20,910

get their batteries charged
and then go back and perform.

684

00:25:20,910 --> 00:25:22,530

So that man started ICTP

685

00:25:22,530 --> 00:25:25,560

and I was fortunate that
I went there in 1976.

686

00:25:25,560 --> 00:25:27,480
I spent nearly three months every year

687

00:25:27,480 --> 00:25:29,250
for the next 20, 30 years.

688

00:25:29,250 --> 00:25:31,500
I became an associate, I
became a staff associate,

689

00:25:31,500 --> 00:25:33,748
then I ran some colleges
there, spring colleges

690

00:25:33,748 --> 00:25:36,900
and I also ran about
12 successful workshops

691

00:25:36,900 --> 00:25:39,360
because there is a very good
infrastructure, good help

692

00:25:39,360 --> 00:25:41,640
and you could do all these things.

693

00:25:41,640 --> 00:25:45,023
It started with theoretical
physics, which is,

694

00:25:45,023 --> 00:25:47,610
you know, an important
component of modern science.

695

00:25:47,610 --> 00:25:49,740
There are many capable people
in third world countries,

696

00:25:49,740 --> 00:25:52,140
but because of isolation,
they are not able to catch up,

697

00:25:52,140 --> 00:25:53,460
so bring them together.

698

00:25:53,460 --> 00:25:56,100
So it was doing the service extremely well

699

00:25:56,100 --> 00:25:58,314
and then I grew up there.

700

00:25:58,314 --> 00:26:00,360
So I met Professor Salam several times.

701

00:26:00,360 --> 00:26:01,530
I have seen him in action

702

00:26:01,530 --> 00:26:03,990
and his passion for people and science.

703

00:26:03,990 --> 00:26:05,100
So that's why I gave a talk.

704

00:26:05,100 --> 00:26:06,750
And it definitely helped my career.

705

00:26:06,750 --> 00:26:11,750
A I said in my talk, I met my
hero, P.W. Anderson at ICTP,

706

00:26:13,830 --> 00:26:15,570
accidentally I should say,

707

00:26:15,570 --> 00:26:18,720
because he gave a beautiful
talk and I thought that's it.

708

00:26:18,720 --> 00:26:21,607
Then my host Irir Torsati came
and dragged me and he said,

709

00:26:21,607 --> 00:26:23,640
"Anderson is free, please
go and talk to him."

710

00:26:23,640 --> 00:26:25,230
I was reluctant to talk to him.

711

00:26:25,230 --> 00:26:26,790
He was too big for me.

712

00:26:26,790 --> 00:26:27,660
- You were intimidated?

713

00:26:27,660 --> 00:26:29,080
- No, he was a nice man.

714

00:26:29,080 --> 00:26:30,540
He is a Nobel Laureate already

715

00:26:30,540 --> 00:26:32,820
and he has produced Nobel Prizes.

716

00:26:32,820 --> 00:26:35,520
So I was kind of feeling
reluctant to meet him.

717

00:26:35,520 --> 00:26:36,630
Then I was forced to meet him.

718

00:26:36,630 --> 00:26:38,370
then that's how it began.

719

00:26:38,370 --> 00:26:41,280

So bringing people together
is one of the important jobs

720

00:26:41,280 --> 00:26:44,280
spontaneously meeting comes naturally.

721

00:26:44,280 --> 00:26:46,590
So I was fortunate that I was in ICTP.

722

00:26:46,590 --> 00:26:48,870
Then I went to Princeton for three years.

723

00:26:48,870 --> 00:26:51,180
Again, it's a very interesting thing.

724

00:26:51,180 --> 00:26:54,630
In November '84, the
first year I was there,

725

00:26:54,630 --> 00:26:56,970
there was a beautiful
talk by John Hopfield,

726

00:26:56,970 --> 00:26:59,250
the father of neural network.

727

00:26:59,250 --> 00:27:01,440
John was a good friend of Phil Anderson.

728

00:27:01,440 --> 00:27:04,470
Since I was already interested
in biology from a distance,

729

00:27:04,470 --> 00:27:05,847
so I was fascinated by the talk,

730

00:27:05,847 --> 00:27:07,260
and in a moment of weakness,

731

00:27:07,260 --> 00:27:09,180

I thought I have
understood what is a brain,

732

00:27:09,180 --> 00:27:11,100

it was one of those illusions

733

00:27:11,100 --> 00:27:13,150

because John gave such a beautiful talk

734

00:27:13,150 --> 00:27:17,220

about brain and Hebb's Rule
and connections, pruning

735

00:27:17,220 --> 00:27:18,690

and then basal attraction

736

00:27:18,690 --> 00:27:21,060

and things that I could
understand, relate to.

737

00:27:21,060 --> 00:27:22,320

So it was fascinating.

738

00:27:22,320 --> 00:27:25,650

Then I decided, next moment
I would work on neurobiology.

739

00:27:25,650 --> 00:27:27,030

So at Princeton.

740

00:27:27,030 --> 00:27:29,130

And when I told this to Phil
Anderson, he encouraged me.

741

00:27:29,130 --> 00:27:32,130

He said, "It's a fantastic
decision, please go."

742

00:27:32,130 --> 00:27:34,680

So he said, "Don't worry
about doing metaphysics.

743

00:27:34,680 --> 00:27:37,113

You are here, we are happy,
do whatever you like."

744

00:27:37,113 --> 00:27:40,170

So I spent two years
learning neurobiology,

745

00:27:40,170 --> 00:27:42,090

and it's a very tough subject.

746

00:27:42,090 --> 00:27:45,240

I even participated in the
conference at Santa Barbara.

747

00:27:45,240 --> 00:27:48,960

The date was neurobiology for
physicists, it was a workshop.

748

00:27:48,960 --> 00:27:50,760

And the workshop was really special.

749

00:27:50,760 --> 00:27:52,440

Only neuroscientists spoke.

750

00:27:52,440 --> 00:27:54,780

Even John Hopkins was in the audience.

751

00:27:54,780 --> 00:27:56,670

But the point is neurobiologists

752

00:27:56,670 --> 00:27:58,320

would make fun of physicists.

753

00:27:58,320 --> 00:28:00,720
They say, these physicists come
and in one day make a model

754
00:28:00,720 --> 00:28:02,700
and get away with it.

755
00:28:02,700 --> 00:28:04,290
Neuroscience is really complicated.

756
00:28:04,290 --> 00:28:06,930
So they will tell
clinical facts, this fact.

757
00:28:06,930 --> 00:28:08,040
So it was a good dialogue

758
00:28:08,040 --> 00:28:10,140
between two different
communities with different views

759
00:28:10,140 --> 00:28:12,750
because we think some
simplified model for them.

760
00:28:12,750 --> 00:28:14,880
Simplified models are useless

761
00:28:14,880 --> 00:28:17,190
'cause for practical clinicians and so on.

762
00:28:17,190 --> 00:28:19,860
Whereas for general
understanding, it's important.

763
00:28:19,860 --> 00:28:23,850
I was spending two years very
seriously thinking about that.

764

00:28:23,850 --> 00:28:26,970
Then high temperature, super
connected to revolution broke.

765
00:28:26,970 --> 00:28:29,280
Then it shifted my
direction and I gave up,

766
00:28:29,280 --> 00:28:32,160
I started working with
Anderson on those problems.

767
00:28:32,160 --> 00:28:33,660
So those three years at Princeton

768
00:28:33,660 --> 00:28:35,610
was memorable in many, many respects,

769
00:28:35,610 --> 00:28:39,150
met great people, started
thinking about great problems.

770
00:28:39,150 --> 00:28:41,010
- I remember in your talk on Friday,

771
00:28:41,010 --> 00:28:46,010
you said that that initial
trip to ICTP in 1976,

772
00:28:46,860 --> 00:28:48,420
because you had a travel fellowship,

773
00:28:48,420 --> 00:28:50,790
that that launched your
career essentially.

774
00:28:50,790 --> 00:28:52,140
And it sounds like the place,

775

00:28:52,140 --> 00:28:54,600
ICTP is designed to help launch careers

776
00:28:54,600 --> 00:28:58,020
for those who may not be
able to launch them otherwise

777
00:28:58,020 --> 00:29:00,790
because of where they're from
or how much money they have.

778
00:29:00,790 --> 00:29:03,180
- Yeah, I know a lot of
students attended your talk

779
00:29:03,180 --> 00:29:06,810
and postdocs and researchers
and also administrative staff.

780
00:29:06,810 --> 00:29:08,310
It was accessible to everyone,

781
00:29:08,310 --> 00:29:11,160
and we had a few questions
sent in as follow-up.

782
00:29:11,160 --> 00:29:14,040
So maybe let's first play
the question from Anna Kanur.

783
00:29:14,040 --> 00:29:16,230
She's a PSI student here.

784
00:29:16,230 --> 00:29:17,580
- Okay.

785
00:29:17,580 --> 00:29:19,470
- In a recent talk at Perimeter,

786

00:29:19,470 --> 00:29:21,750
you stated that in building up

787
00:29:21,750 --> 00:29:24,270
the International Center
for Theoretical Physics,

788
00:29:24,270 --> 00:29:27,420
Professor Abdus Salam
had a profound impact

789
00:29:27,420 --> 00:29:32,040
in making scientific exchange
and education more accessible.

790
00:29:32,040 --> 00:29:35,640
But you also said that he would
do things differently today.

791
00:29:35,640 --> 00:29:36,473
So how would you envision

792
00:29:36,473 --> 00:29:41,473
a truly impactful scientific institution

793
00:29:41,940 --> 00:29:43,923
in the early 21st century?

794
00:29:45,000 --> 00:29:46,680
- Having said that very quickly,

795
00:29:46,680 --> 00:29:49,650
I don't know how I will do
it, but let me tell you,

796
00:29:49,650 --> 00:29:52,380
when Salam started, it was early '60's.

797
00:29:52,380 --> 00:29:54,720

It's nearly 60 years ago.

798

00:29:54,720 --> 00:29:56,790

The world was connected

799

00:29:56,790 --> 00:29:59,430

by electromagnetic radiation
and wireless communications

800

00:29:59,430 --> 00:30:00,810

but it's very different now.

801

00:30:00,810 --> 00:30:03,300

So let me give you one specific example

802

00:30:03,300 --> 00:30:05,940

that I recently gave a talk.

803

00:30:05,940 --> 00:30:07,740

Salam will start, for example,

804

00:30:07,740 --> 00:30:11,460

encouraging private
donors to contribute money

805

00:30:11,460 --> 00:30:14,910

and use lots of programs
which are connected by

806

00:30:14,910 --> 00:30:18,133

suppose I had no opportunity
to come from Bangalore to ICTP.

807

00:30:18,133 --> 00:30:19,590

I had no travel fellowship.

808

00:30:19,590 --> 00:30:21,750

I could have still benefited by Zoom talks

809

00:30:21,750 --> 00:30:23,670

because some of the Zoom
talks are very inspiring,

810

00:30:23,670 --> 00:30:26,520

I could even talk, so that kind
of things would've happened.

811

00:30:26,520 --> 00:30:27,990

It is in this context I was telling you

812

00:30:27,990 --> 00:30:30,510

about the experience of Einstein

813

00:30:30,510 --> 00:30:35,510

and how it could be used in
modern times to propagate signs

814

00:30:35,786 --> 00:30:38,310

and get people from third world countries

815

00:30:38,310 --> 00:30:39,930

to get deeply involved in science.

816

00:30:39,930 --> 00:30:42,390

So the first part of my answer is

817

00:30:42,390 --> 00:30:45,120

people are not able to go to
ICTP or come to Perimeter,

818

00:30:45,120 --> 00:30:46,410

there can be Zoom talks.

819

00:30:46,410 --> 00:30:48,570

With (indistinct), I had a discussion

820

00:30:48,570 --> 00:30:51,420

and we tried very hard
to implement it in India.

821

00:30:51,420 --> 00:30:54,330
It was called PSA mirror at Chennai.

822

00:30:54,330 --> 00:30:58,440
The idea is to employ our
own post docs as tutors

823

00:30:58,440 --> 00:31:01,203
and run the video lectures from here

824

00:31:01,203 --> 00:31:03,870
and get about 30 students from Chennai,

825

00:31:03,870 --> 00:31:06,090
just finished their
master's, motivated students,

826

00:31:06,090 --> 00:31:09,660
and give them the same
assignments, so it's mirroring it.

827

00:31:09,660 --> 00:31:11,337
The office was very enthusiastic and so on

828

00:31:11,337 --> 00:31:13,470
and then finally there
was some budget crunch

829

00:31:13,470 --> 00:31:14,790
and then it fell down.

830

00:31:14,790 --> 00:31:16,260
Because of internet connections

831

00:31:16,260 --> 00:31:18,720
and because of this

new fantastic facility,

832

00:31:18,720 --> 00:31:20,430
Salam will do it differently,
that's what I mean.

833

00:31:20,430 --> 00:31:23,490
The personal presence
will be definitely good,

834

00:31:23,490 --> 00:31:25,590
but then in case you cannot do it,

835

00:31:25,590 --> 00:31:27,300
what is the next best?

836

00:31:27,300 --> 00:31:30,300
Then in that context, I
also wanted to tell you

837

00:31:30,300 --> 00:31:32,880
Neil Turok has this fantastic

838

00:31:32,880 --> 00:31:35,010
African Institute of Mathematical Sciences

839

00:31:35,010 --> 00:31:36,030
and that they started something

840

00:31:36,030 --> 00:31:38,220
called Next Einstein from Africa.

841

00:31:38,220 --> 00:31:40,110
So I gave a talk in India,

842

00:31:40,110 --> 00:31:42,360
Next Einstein from Developing Countries.

843

00:31:42,360 --> 00:31:45,540
This was inspiration that
came from Einstein himself.

844
00:31:45,540 --> 00:31:49,890
Einstein, when he joined ETH
at the Hague in Switzerland

845
00:31:49,890 --> 00:31:51,630
as five year course student

846
00:31:51,630 --> 00:31:52,560
from day number one,

847
00:31:52,560 --> 00:31:55,230
he collected about 10,
12 like-minded students

848
00:31:55,230 --> 00:31:57,360
and started discussing
physics, philosophy,

849
00:31:57,360 --> 00:32:01,020
religion, everything every
day for three hours intensely.

850
00:32:01,020 --> 00:32:04,320
Sometimes they came across a
book by a famous mathematician

851
00:32:04,320 --> 00:32:06,813
Henri Poincare, great mathematician.

852
00:32:06,813 --> 00:32:08,880
The title of the book is
"Science and Hypothesis".

853
00:32:08,880 --> 00:32:10,440
In fact, I have a copy of that book.

854

00:32:10,440 --> 00:32:11,910
Poincare was a generalist.

855

00:32:11,910 --> 00:32:13,470
He knew a lot of science.

856

00:32:13,470 --> 00:32:14,370
So he eliminated

857

00:32:14,370 --> 00:32:17,220
what are the unsolved
problems in science now.

858

00:32:17,220 --> 00:32:19,610
So three of the striking
problems that he put

859

00:32:19,610 --> 00:32:21,870
was in Brownian motion,
photoelectric effect,

860

00:32:21,870 --> 00:32:23,400
and is there ether?

861

00:32:23,400 --> 00:32:26,610
So these young minds started
discussing that problem

862

00:32:26,610 --> 00:32:28,860
fearlessly without any inhibition

863

00:32:28,860 --> 00:32:32,160
and slowly dug deep
and equipped themselves

864

00:32:32,160 --> 00:32:34,200
with enough mathematics and phenomenology.

865

00:32:34,200 --> 00:32:36,600
Because there are 10 people,
everybody is strong in one way

866
00:32:36,600 --> 00:32:38,820
so they complimented each other.

867
00:32:38,820 --> 00:32:39,653
In three years,

868
00:32:39,653 --> 00:32:41,310
apparently teachers
started envying the group

869
00:32:41,310 --> 00:32:44,343
because these boys and girls
knew more than the teachers.

870
00:32:45,510 --> 00:32:48,510
Then in five years, they
even started writing papers.

871
00:32:48,510 --> 00:32:51,300
Minkowski was one of the things
and Melegos was also there.

872
00:32:51,300 --> 00:32:52,133
For some reasons,

873
00:32:52,133 --> 00:32:53,700
Einstein did not get
a research fellowship.

874
00:32:53,700 --> 00:32:55,350
He became a patent of his clerk

875
00:32:55,350 --> 00:32:57,750
thanks to one of the fathers of this group

876

00:32:57,750 --> 00:33:00,330
and then he continued
in the name academia.

877
00:33:00,330 --> 00:33:02,280
They would meet in the
evenings and discuss.

878
00:33:02,280 --> 00:33:05,490
And then in few years,
they wrote the famous 1905

879
00:33:05,490 --> 00:33:08,280
paper on Brownian motion,
relativity theory and so on.

880
00:33:08,280 --> 00:33:11,730
So what I said was, now I
will go to a remote village,

881
00:33:11,730 --> 00:33:14,940
it could be in Africa
or it could be in India,

882
00:33:14,940 --> 00:33:17,130
nothing is remote for the satellite.

883
00:33:17,130 --> 00:33:19,770
Suppose you give everybody a cheap tablet.

884
00:33:19,770 --> 00:33:23,010
So let them sit and go
to internet, all courses,

885
00:33:23,010 --> 00:33:24,660
MIT, Harvard courses are available,

886
00:33:24,660 --> 00:33:28,110
start with the element,
Perimeter courses are available,

887
00:33:28,110 --> 00:33:30,570
and sit together every day for two hours,

888
00:33:30,570 --> 00:33:33,660
whatever Einstein had,
whatever facilities they had,

889
00:33:33,660 --> 00:33:37,800
it's there in the library, so
they can go deeply into it.

890
00:33:37,800 --> 00:33:41,220
and if such things are initiated
and if they're encouraged,

891
00:33:41,220 --> 00:33:43,380
there'll be many more Einstein's
from all over the world.

892
00:33:43,380 --> 00:33:44,700
That was my point.

893
00:33:44,700 --> 00:33:47,760
In fact, my professor,
Rangarajan in Bangalore,

894
00:33:47,760 --> 00:33:49,290
he was inspired by Einstein.

895
00:33:49,290 --> 00:33:51,570
That way, he said
theoretical should be done

896
00:33:51,570 --> 00:33:53,280
through group discussion.

897
00:33:53,280 --> 00:33:55,170
Everybody has a strength

and you can share it.

898

00:33:55,170 --> 00:33:57,840

So I wanted to say that
about this Anna's question.

899

00:33:57,840 --> 00:33:59,280

Thanks to modern technology,

900

00:33:59,280 --> 00:34:01,830

there is no isolation in some sense.

901

00:34:01,830 --> 00:34:02,968

Like minded people can work together

902

00:34:02,968 --> 00:34:05,760

cause nothing like group
discussion among peers

903

00:34:05,760 --> 00:34:09,510

because then you have
no inhibition, no fear,

904

00:34:09,510 --> 00:34:12,180

you can ask stupid questions,
no question is stupid.

905

00:34:12,180 --> 00:34:14,550

- That notion that the next Einstein

906

00:34:14,550 --> 00:34:17,280

could come from anywhere in the world

907

00:34:17,280 --> 00:34:21,060

is really helped by the idea
that now at relatively low cost

908

00:34:21,060 --> 00:34:23,520

people can do what you couldn't do.

909

00:34:23,520 --> 00:34:26,550

And so it opens up doors to more people.

910

00:34:26,550 --> 00:34:28,950

- Thanks to arranging
these Abdus Salam lectures,

911

00:34:28,950 --> 00:34:30,720

I started going back to my lecture

912

00:34:30,720 --> 00:34:32,880

on Next Einstein from
Developing Countries.

913

00:34:32,880 --> 00:34:34,800

This article appeared somewhere.

914

00:34:34,800 --> 00:34:37,800

I want to rewrite it and put
it more accessible to people

915

00:34:37,800 --> 00:34:39,600

because people can think about it.

916

00:34:39,600 --> 00:34:42,300

This a new power because it's
also good for young minds

917

00:34:42,300 --> 00:34:44,100

because young children are,

918

00:34:44,100 --> 00:34:45,840

you know, they don't know
what to do these days.

919

00:34:45,840 --> 00:34:47,130

They're isolated,

920
00:34:47,130 --> 00:34:49,680
but they can be united also
through this group discussion

921
00:34:49,680 --> 00:34:52,050
and they can make useful things.

922
00:34:52,050 --> 00:34:53,580
- I think this is such an important point

923
00:34:53,580 --> 00:34:57,690
that technology can enable
us to include more people

924
00:34:57,690 --> 00:34:58,523
in these discussions.

925
00:34:58,523 --> 00:35:00,120
And I think this leads in really well

926
00:35:00,120 --> 00:35:01,680
to another question that was sent in.

927
00:35:01,680 --> 00:35:05,282
This one is from Estelle Inac,
she's a research scientist.

928
00:35:05,282 --> 00:35:06,115
- Yeah, Estelle, yes.

929
00:35:06,115 --> 00:35:07,448
- And we've interviewed her
for our podcast as well.

930
00:35:07,448 --> 00:35:09,227
- Oh, wonderful.

931
00:35:09,227 --> 00:35:11,310

- Hello, Baskaran.

932

00:35:11,310 --> 00:35:13,260

Thank you very much for
the time that you took

933

00:35:13,260 --> 00:35:14,217

to talk with me

934

00:35:14,217 --> 00:35:18,630

and for the very nice seminar
that you gave on Friday.

935

00:35:18,630 --> 00:35:20,970

So I have two questions for you today

936

00:35:20,970 --> 00:35:23,430

and my first question is the following,

937

00:35:23,430 --> 00:35:27,030

In your opinion, why
are developing countries

938

00:35:27,030 --> 00:35:29,190

still lagging as far as progress

939

00:35:29,190 --> 00:35:32,610

in cutting edge theoretical
physics is concerned?

940

00:35:32,610 --> 00:35:33,930

And the second question is,

941

00:35:33,930 --> 00:35:37,800

what should be done to close
the gap of research excellence

942

00:35:37,800 --> 00:35:39,180

with the developed world?

943

00:35:39,180 --> 00:35:40,180

Thank you very much.

944

00:35:41,250 --> 00:35:42,990

- We take a developing country,

945

00:35:42,990 --> 00:35:44,580

they have many, many problems,

946

00:35:44,580 --> 00:35:48,510

starting from bad politicians
to water, poverty,

947

00:35:48,510 --> 00:35:51,900

disease and so on so
they have to prioritize.

948

00:35:51,900 --> 00:35:53,760

Politicians always find it convenient

949

00:35:53,760 --> 00:35:56,220

to prioritize something
else rather than education.

950

00:35:56,220 --> 00:35:57,900

So we have to slowly convince them.

951

00:35:57,900 --> 00:35:59,340

I think it's a question of perception

952

00:35:59,340 --> 00:36:01,860

because the kind of
vision that Perimeter has,

953

00:36:01,860 --> 00:36:04,920

that theoretical physics
eventually helps technology,

954
00:36:04,920 --> 00:36:06,780
it's not obvious to people in development.

955
00:36:06,780 --> 00:36:10,440
They say, "No, no, we have a
problem, we want a solution.

956
00:36:10,440 --> 00:36:12,120
We can't be waiting for 100 years"

957
00:36:12,120 --> 00:36:13,350
which may be relevant.

958
00:36:13,350 --> 00:36:15,270
So people like Estelle,

959
00:36:15,270 --> 00:36:17,520
you should go and
convince your government,

960
00:36:17,520 --> 00:36:19,260
educate them, it'll take time.

961
00:36:19,260 --> 00:36:21,420
For example, in my own country,

962
00:36:21,420 --> 00:36:22,440
soon after independence,

963
00:36:22,440 --> 00:36:24,630
it was realized by the
leaders in those days

964
00:36:24,630 --> 00:36:26,580
that science and technology
is very important.

965
00:36:26,580 --> 00:36:29,430

So unlike many parallel
neighboring countries,

966

00:36:29,430 --> 00:36:31,860
we had some men late
and if I tell the name,

967

00:36:31,860 --> 00:36:34,680
I don't want to be belong
to any particular politics,

968

00:36:34,680 --> 00:36:37,680
you know, this leader by
named Jawaharlal Nehru,

969

00:36:37,680 --> 00:36:39,840
he worked with Mahatma
Gandhi for liberation now

970

00:36:39,840 --> 00:36:42,840
in India and so on, he envisioned
that science is important,

971

00:36:42,840 --> 00:36:43,890
science and technology.

972

00:36:43,890 --> 00:36:47,490
So from the beginning, he
put money and good people,

973

00:36:47,490 --> 00:36:49,920
so we are reaping that benefit now.

974

00:36:49,920 --> 00:36:52,290
it has not happened in
many other countries.

975

00:36:52,290 --> 00:36:54,660
It is a question of
convincing people over time.

976

00:36:54,660 --> 00:36:56,190

And also in India,

977

00:36:56,190 --> 00:36:57,960

many of my colleagues complain,

978

00:36:57,960 --> 00:36:59,520

they are very bitter

about what is happening

979

00:36:59,520 --> 00:37:00,720

in politics and so on.

980

00:37:00,720 --> 00:37:03,390

I tell them that India

is an end democracy.

981

00:37:03,390 --> 00:37:05,700

We are 1.5 billion people.

982

00:37:05,700 --> 00:37:07,830

We got freedom only 60 years ago.

983

00:37:07,830 --> 00:37:09,870

100 years from now will be much better.

984

00:37:09,870 --> 00:37:11,693

Then they get angry.

985

00:37:11,693 --> 00:37:15,033

But I'm just saying that,

you know, things take time,

986

00:37:15,033 --> 00:37:16,350

there's a time scale for everything.

987

00:37:16,350 --> 00:37:18,960

So we should be patient
but constantly trying.

988

00:37:18,960 --> 00:37:22,410
- It seems like time
though for richer nations

989

00:37:22,410 --> 00:37:24,030
is a luxury that they have

990

00:37:24,030 --> 00:37:27,000
because they can afford to
address immediate problems,

991

00:37:27,000 --> 00:37:28,320
medium term problems.

992

00:37:28,320 --> 00:37:30,690
It seems in the developing
world, like you said,

993

00:37:30,690 --> 00:37:34,620
the instinct would be let's
fix the immediate problems

994

00:37:34,620 --> 00:37:35,880
right in front of us.

995

00:37:35,880 --> 00:37:40,467
So how do you convince
politicians to look maybe 10, 50,

996

00:37:40,467 --> 00:37:42,300
100 years into the future,

997

00:37:42,300 --> 00:37:44,100
which is the timeframe of some

998

00:37:44,100 --> 00:37:45,393

fundamental science.

- So for example,

999

00:37:45,393 --> 00:37:49,020

what I will do is there

is a very famous book

1000

00:37:49,020 --> 00:37:51,000

by former director

1001

00:37:51,000 --> 00:37:53,393

of Institute for Advanced

Studies at Princeton.

1002

00:37:53,393 --> 00:37:56,100

The title of the book is

"Usefulness of Useless Science".

1003

00:37:56,100 --> 00:37:57,780

He hired Einstein and so on.

1004

00:37:57,780 --> 00:38:01,680

So we have to translate such
books into regional languages.

1005

00:38:01,680 --> 00:38:03,510

But to me, more urgent thing is

1006

00:38:03,510 --> 00:38:06,660

to start group activity
among enthusiastic children

1007

00:38:06,660 --> 00:38:07,980

and the scientists,

1008

00:38:07,980 --> 00:38:09,330

because Abdus Salam

1009

00:38:09,330 --> 00:38:12,090

return from Princeton and went to his town

1010

00:38:12,090 --> 00:38:13,950

and he was isolated.

1011

00:38:13,950 --> 00:38:15,390

Now if Abdus Salam goes,

1012

00:38:15,390 --> 00:38:17,670

there is no reason why

he should be isolated.

1013

00:38:17,670 --> 00:38:20,580

He can have Zoom meeting

every day, two Zoom meeting,

1014

00:38:20,580 --> 00:38:21,730

which is happening now.

1015

00:38:22,620 --> 00:38:24,720

Then, politicians appreciate it.

1016

00:38:24,720 --> 00:38:27,450

Internet should be used in

a much more creative way,

1017

00:38:27,450 --> 00:38:29,550

bringing people together.

1018

00:38:29,550 --> 00:38:32,370

- It seems like a lot

of the challenges about,

1019

00:38:32,370 --> 00:38:33,900

you know, bringing people together

1020

00:38:33,900 --> 00:38:35,760

who maybe have different experiences,

1021
00:38:35,760 --> 00:38:37,260
and it actually kind of reminds me

1022
00:38:37,260 --> 00:38:39,300
of something you said in your paper

1023
00:38:39,300 --> 00:38:42,480
when you were describing
condensed matter physicists

1024
00:38:42,480 --> 00:38:44,190
collaborating with biologists.

1025
00:38:44,190 --> 00:38:46,267
And so in your paper that was called

1026
00:38:46,267 --> 00:38:48,330
"Condensed matter, Physics
Biology Resonance",

1027
00:38:48,330 --> 00:38:50,497
I wrote down something
you wrote which was that,

1028
00:38:50,497 --> 00:38:53,790
"the urgent problem facing
a hardcore biologist

1029
00:38:53,790 --> 00:38:55,170
is often very different

1030
00:38:55,170 --> 00:38:58,530
from what a physicist
genuinely interested in biology

1031
00:38:58,530 --> 00:39:01,080
is capable of solving
in a short time period."

1032
00:39:01,080 --> 00:39:02,400
And so I think here too,

1033
00:39:02,400 --> 00:39:03,900
you maybe have the challenge

1034
00:39:03,900 --> 00:39:07,470
that these two types of
scientists are approaching things

1035
00:39:07,470 --> 00:39:09,840
from a different setup or a
different way of thinking.

1036
00:39:09,840 --> 00:39:12,630
So can you maybe talk
about that challenge there?

1037
00:39:12,630 --> 00:39:13,800
- Yeah, very good.

1038
00:39:13,800 --> 00:39:17,760
I will give you an
example of Stan Liebler.

1039
00:39:17,760 --> 00:39:19,500
So he was a condensed matter theorist,

1040
00:39:19,500 --> 00:39:21,660
statist school mechanic
in Chicago or somewhere.

1041
00:39:21,660 --> 00:39:23,580
He slowly got into biology.

1042
00:39:23,580 --> 00:39:25,230
Now he's at the Institute
for Advanced Studies

1043
00:39:25,230 --> 00:39:26,550
a professor of biology.

1044
00:39:26,550 --> 00:39:27,903
He used to do wet biology.

1045
00:39:29,173 --> 00:39:32,580
So yeah biologist, suppose
you go and tell him

1046
00:39:32,580 --> 00:39:34,380
that this model is important, he will not,

1047
00:39:34,380 --> 00:39:36,660
because he's working very, very hard,

1048
00:39:36,660 --> 00:39:39,240
one Nobel Laureate from
Stanford, I forget his name,

1049
00:39:39,240 --> 00:39:42,660
he spent his whole life
separating out one enzyme,

1050
00:39:42,660 --> 00:39:44,760
one particular enzyme and got Nobel Prize,

1051
00:39:44,760 --> 00:39:46,920
but he's not interested in
the whole quantum biology

1052
00:39:46,920 --> 00:39:48,030
or you know, holistic things.

1053
00:39:48,030 --> 00:39:50,730
So there are people who
have their own compulsions.

1054

00:39:50,730 --> 00:39:53,385
So you like to tell them that
these things are important,

1055
00:39:53,385 --> 00:39:55,920
you know like in nature,
there are a variety of things,

1056
00:39:55,920 --> 00:39:57,855
there is desert, there is Mount Everest,

1057
00:39:57,855 --> 00:39:59,190
there is this and that.

1058
00:39:59,190 --> 00:40:00,780
Imagine a world without ocean,

1059
00:40:00,780 --> 00:40:04,127
imagine a world without
desert, so it's important.

1060
00:40:04,127 --> 00:40:05,670
In that sense, yeah theoretical biology,

1061
00:40:05,670 --> 00:40:06,810
in the long run, it will definitely,

1062
00:40:06,810 --> 00:40:08,370
but it has to be convinced,

1063
00:40:08,370 --> 00:40:09,960
and it's happening in many places.

1064
00:40:09,960 --> 00:40:12,420
Because I remember, once
there was a colloquium

1065
00:40:12,420 --> 00:40:14,160
at the Institute for Advanced Studies.

1066

00:40:14,160 --> 00:40:15,420

Frank Wilczek had invited

1067

00:40:15,420 --> 00:40:19,050

some very distinguished biologists
from MIT to give a talk.

1068

00:40:19,050 --> 00:40:22,146

So he just, you know, made
fun of theoretical physicists.

1069

00:40:22,146 --> 00:40:23,580

He said, "That you guys
come into few talks

1070

00:40:23,580 --> 00:40:25,020

and you come with a model.

1071

00:40:25,020 --> 00:40:26,520

What I'm going through today

1072

00:40:26,520 --> 00:40:28,773

is a hypothesis which I made 20 years ago

1073

00:40:28,773 --> 00:40:32,040

and it has taken 20 years for
me to prove that hypothesis."

1074

00:40:32,040 --> 00:40:33,840

But on the other hand,
what he says is true,

1075

00:40:33,840 --> 00:40:37,020

but then there are also people
who have to see the forest

1076

00:40:37,020 --> 00:40:39,360

from a distance and you

know, it's very important.

1077

00:40:39,360 --> 00:40:40,193

And it's happening.

1078

00:40:40,193 --> 00:40:41,340

Compared to 50 years ago,

1079

00:40:41,340 --> 00:40:44,163

now biology, physics
interaction is amazing.

1080

00:40:45,150 --> 00:40:47,340

- When we first chatted a week or so ago,

1081

00:40:47,340 --> 00:40:50,340

I was so fascinated about
the conversation we had

1082

00:40:50,340 --> 00:40:51,540

about quantum biology,

1083

00:40:51,540 --> 00:40:53,712

partly 'cause it's an area I
haven't learned much about,

1084

00:40:53,712 --> 00:40:57,180

but also because it's the
kind of thing that we can

1085

00:40:57,180 --> 00:41:01,050

in a sense relate to because
we are biological entities.

1086

00:41:01,050 --> 00:41:02,430

So you know, we talked about

1087

00:41:02,430 --> 00:41:06,450

how there may be quantum

processes in bird migration

1088

00:41:06,450 --> 00:41:11,430

or in how bacteria use the
magnetic field of the world.

1089

00:41:11,430 --> 00:41:12,870

Can you speak a little bit about

1090

00:41:12,870 --> 00:41:16,620

how biology and theoretical
physics are coming together

1091

00:41:16,620 --> 00:41:18,300

in your own work?

1092

00:41:18,300 --> 00:41:21,513

- Okay, see I should confess
that I'm not an expert.

1093

00:41:22,444 --> 00:41:24,103

On my webpage in the
institute, I don't find this,

1094

00:41:24,103 --> 00:41:28,433

I had a sentence about
myself interested in biology.

1095

00:41:28,433 --> 00:41:29,910

It said, "Love at a distance

1096

00:41:29,910 --> 00:41:32,040

and I am longing for a residence with her

1097

00:41:32,040 --> 00:41:33,150

in the last 40 years."

1098

00:41:33,150 --> 00:41:34,470

- Unrequited love?

1099

00:41:34,470 --> 00:41:36,660

- Exactly, well yeah, that's kind of.

1100

00:41:36,660 --> 00:41:40,140

So two years I spent thinking
of going into neurobiology

1101

00:41:40,140 --> 00:41:42,330

but that was too short, then I came back.

1102

00:41:42,330 --> 00:41:45,510

Since then, suppose somebody
gives me a paper on "Nature"

1103

00:41:45,510 --> 00:41:47,370

or "Science" magazine,

1104

00:41:47,370 --> 00:41:50,460

I don't go to physics
section, I go to biology

1105

00:41:50,460 --> 00:41:52,830

to you see what is going
on, just to get an idea.

1106

00:41:52,830 --> 00:41:55,140

And also, I gave a full
fledged course on biology

1107

00:41:55,140 --> 00:41:58,410

from a very good book at my
institute many years ago.

1108

00:41:58,410 --> 00:42:00,600

Just no equation, just phenomena

1109

00:42:00,600 --> 00:42:02,730

because physicists are not used to it.

1110

00:42:02,730 --> 00:42:05,366

- It was biology for
physicists, this course?

1111

00:42:05,366 --> 00:42:06,776

- Yeah, biology for physicists,

1112

00:42:06,776 --> 00:42:08,786

it was a six months full fledged course.

1113

00:42:08,786 --> 00:42:10,380

Bruce Alberts is a very famous biologist.

1114

00:42:10,380 --> 00:42:12,000

He got Nobel Prize and so on.

1115

00:42:12,000 --> 00:42:14,460

He has a book called
"Essential Cell Biology",

1116

00:42:14,460 --> 00:42:16,230

very nice book, very descriptive,

1117

00:42:16,230 --> 00:42:19,020

so I covered the entire
book for my course.

1118

00:42:19,020 --> 00:42:22,050

So I have been enjoying
it from a distance.

1119

00:42:22,050 --> 00:42:26,310

So I have not contributed any
even epsilon to real progress.

1120

00:42:26,310 --> 00:42:29,580

In fact, once I had a post-doc
who started working with me

1121
00:42:29,580 --> 00:42:32,040
on some issues in photosynthesis,
quantum equivalence,

1122
00:42:32,040 --> 00:42:35,100
then he left, but I
seriously think about it.

1123
00:42:35,100 --> 00:42:37,860
- It's more of a passion
than your line of?

1124
00:42:37,860 --> 00:42:39,300
- Two examples that you gave.

1125
00:42:39,300 --> 00:42:42,570
In fact, it's almost
confirmed in bionavigation,

1126
00:42:42,570 --> 00:42:46,200
the theory due to Klaus Schulten
is correct in the sense.

1127
00:42:46,200 --> 00:42:47,460
So the challenges of falling,

1128
00:42:47,460 --> 00:42:51,300
that is birds seem to find the
direction of magnetic field

1129
00:42:51,300 --> 00:42:52,710
in their migration.

1130
00:42:52,710 --> 00:42:56,010
But magnetic field is very weak, one goes.

1131
00:42:56,010 --> 00:42:58,590
So if you convert it into

some energy scale in terms of,

1132

00:42:58,590 --> 00:43:00,030

it's one kelvin.

1133

00:43:00,030 --> 00:43:03,300

So we are at 300 kelvins,

how do you do this?

1134

00:43:03,300 --> 00:43:04,443

So Klaus Schulten thought,

1135

00:43:04,443 --> 00:43:07,230

it's called radical pair hypothesis.

1136

00:43:07,230 --> 00:43:09,180

There are some chemical reactions

1137

00:43:09,180 --> 00:43:11,550

in which a radical has an unpaired spin.

1138

00:43:11,550 --> 00:43:13,680

So there is a biradical, two radicals.

1139

00:43:13,680 --> 00:43:15,420

So the two spins are weakly coupled

1140

00:43:15,420 --> 00:43:18,450

and they can form a spin
singlet or a spin triplet.

1141

00:43:18,450 --> 00:43:20,370

Spin triplet is an entangled state.

1142

00:43:20,370 --> 00:43:23,460

A spinning triplet lets
up, is a product state.

1143

00:43:23,460 --> 00:43:25,950
Now depending on the spin state,

1144
00:43:25,950 --> 00:43:28,140
the reaction pathway
can be very different,

1145
00:43:28,140 --> 00:43:29,460
they can bifurcate.

1146
00:43:29,460 --> 00:43:31,140
Klaus Schulten's point was

1147
00:43:31,140 --> 00:43:34,620
this entanglement is
sensed by a nuclear spin

1148
00:43:34,620 --> 00:43:36,810
and then it remembers that.

1149
00:43:36,810 --> 00:43:38,910
I cannot explain it in a very short time.

1150
00:43:38,910 --> 00:43:41,924
So there is very important
role played by nuclear spin,

1151
00:43:41,924 --> 00:43:44,460
which is well isolated
from the environment

1152
00:43:44,460 --> 00:43:47,220
because of the weak coupling
with the rest of the world

1153
00:43:47,220 --> 00:43:48,720
through hyper fan coupling.

1154
00:43:48,720 --> 00:43:51,780

I heard a talk in fact
some years ago at Berkeley,

1155
00:43:51,780 --> 00:43:53,490
Klaus Schulten was sitting next to me,

1156
00:43:53,490 --> 00:43:56,130
somebody confirming his hypothesis.

1157
00:43:56,130 --> 00:43:58,410
It's getting more and more favorable

1158
00:43:58,410 --> 00:44:00,084
from an experimental point of view.

1159
00:44:00,084 --> 00:44:03,750
So in that sense, nuclear
spins are very important.

1160
00:44:03,750 --> 00:44:06,090
Every water molecule has two protons

1161
00:44:06,090 --> 00:44:09,600
and even if you forget the
spin of oxygen nucleus,

1162
00:44:09,600 --> 00:44:11,643
proton spins are, they are like qubit,

1163
00:44:11,643 --> 00:44:13,260
what are they doing?

1164
00:44:13,260 --> 00:44:14,730
Some people have speculated wildly

1165
00:44:14,730 --> 00:44:16,590
so people shy away from it.

1166

00:44:16,590 --> 00:44:20,040
But recently, Matthew
Fisher, one of our deviants,

1167
00:44:20,040 --> 00:44:22,320
has come up with a very concrete idea

1168
00:44:22,320 --> 00:44:25,980
using some molecule where
this entangled nuclear spin,

1169
00:44:25,980 --> 00:44:27,150
even when they are separated,

1170
00:44:27,150 --> 00:44:28,440
they may remain entangled

1171
00:44:28,440 --> 00:44:31,170
because of weak coupling and
it can trigger something,

1172
00:44:31,170 --> 00:44:32,220
we do not know.

1173
00:44:32,220 --> 00:44:34,260
So this is a kind of new friend,

1174
00:44:34,260 --> 00:44:36,420
but people are careful for good reasons.

1175
00:44:36,420 --> 00:44:39,390
People start speculating
without doing calculations.

1176
00:44:39,390 --> 00:44:41,490
They similar is very seriously

1177
00:44:41,490 --> 00:44:43,830
and they say we understand

everything, which is wrong.

1178

00:44:43,830 --> 00:44:45,660

So it is in this field,

1179

00:44:45,660 --> 00:44:48,330

I can see in my last

30, 40 years experience,

1180

00:44:48,330 --> 00:44:49,860

it's the experiment which is pushy.

1181

00:44:49,860 --> 00:44:51,322

Like bird navigation,

1182

00:44:51,322 --> 00:44:53,370

now experiments are confirming

1183

00:44:53,370 --> 00:44:55,200

the hypothesis that Klaus Schulten made.

1184

00:44:55,200 --> 00:44:56,760

- These processes are actually part

1185

00:44:56,760 --> 00:44:58,067

of bird migration?

- Exactly, they've done

1186

00:44:58,067 --> 00:45:00,900

create experiments with cage

and changing magnetic field,

1187

00:45:00,900 --> 00:45:02,430

found the correlations.

1188

00:45:02,430 --> 00:45:03,420

It's amazing.

1189

00:45:03,420 --> 00:45:04,950
It's respected by serious people

1190
00:45:04,950 --> 00:45:07,440
and that they're doing
more and more experiments.

1191
00:45:07,440 --> 00:45:08,610
- From my perspective,

1192
00:45:08,610 --> 00:45:11,160
I've always thought that
quantum processes happen

1193
00:45:11,160 --> 00:45:15,510
in a very, very small, very
isolated, non-biological system

1194
00:45:15,510 --> 00:45:20,510
that we biological animals are
all wet and meaty and large

1195
00:45:21,060 --> 00:45:24,840
and all the things that make
quantum processes not happen.

1196
00:45:24,840 --> 00:45:25,940
- In fact what you are saying is,

1197
00:45:25,940 --> 00:45:27,330
or often people say,

1198
00:45:27,330 --> 00:45:29,850
quantum mechanic starts
at the level of bonding,

1199
00:45:29,850 --> 00:45:32,910
then the rest is chemistry,
rest are reaction rates,

1200

00:45:32,910 --> 00:45:33,750
which was true.

1201

00:45:33,750 --> 00:45:35,720
But however, thanks to experiments,

1202

00:45:35,720 --> 00:45:38,887
we see surprises, like photosynthesis.

1203

00:45:38,887 --> 00:45:42,060
In photosynthesis, photon
gets absorbed by a molecule

1204

00:45:42,060 --> 00:45:43,557
and it gets excited, it's called exciton.

1205

00:45:43,557 --> 00:45:46,680
This exciton people thought
hops from place to place

1206

00:45:46,680 --> 00:45:48,420
and then delivers its energy at the place

1207

00:45:48,420 --> 00:45:50,040
which delivers an electron,

1208

00:45:50,040 --> 00:45:52,110
so it starts an electron
transfer reaction.

1209

00:45:52,110 --> 00:45:53,220
But there was a surprise

1210

00:45:53,220 --> 00:45:55,920
from Toronto schools and other people

1211

00:45:55,920 --> 00:45:58,920
that the exciton remains quantum coherent

1212
00:45:58,920 --> 00:46:00,900
over time scale than we suspected.

1213
00:46:00,900 --> 00:46:03,387
Nature smile at people
that something else happen.

1214
00:46:03,387 --> 00:46:06,900
Now there are many theories to
convince that it is possible

1215
00:46:06,900 --> 00:46:09,690
because after all, biology
is a regulated system,

1216
00:46:09,690 --> 00:46:12,960
we pump energy, could pump
energy to keep a place cool.

1217
00:46:12,960 --> 00:46:16,893
You know, in fact, in the
colloquium that we had last week.

1218
00:46:18,300 --> 00:46:19,380
- Was it Nicole?

1219
00:46:19,380 --> 00:46:20,520
- Yeah, exactly, Nicole.

1220
00:46:20,520 --> 00:46:24,150
I asked her a question because
she said her quantum battery,

1221
00:46:24,150 --> 00:46:25,560
there are applications to photosynthesis.

1222
00:46:25,560 --> 00:46:27,360
I asked her and she sent me a pre-print.

1223

00:46:27,360 --> 00:46:30,750

It's fascinating because
they are implicating

1224

00:46:30,750 --> 00:46:32,760

kind of physics that they have found out

1225

00:46:32,760 --> 00:46:36,150

at the level of single photon
detection in our vision.

1226

00:46:36,150 --> 00:46:39,330

Because it's well known that
vision begins like yeah,

1227

00:46:39,330 --> 00:46:42,120

at the level of detecting a single photon,

1228

00:46:42,120 --> 00:46:45,030

basically it's a long molecule,

1229

00:46:45,030 --> 00:46:48,630

it's confirmation changes from
cis to trans or trans to cis.

1230

00:46:48,630 --> 00:46:52,260

Now apparently for that to
happen in a regulated way,

1231

00:46:52,260 --> 00:46:53,910

you need some of these ideas.

1232

00:46:53,910 --> 00:46:55,470

So it's a beginning,

1233

00:46:55,470 --> 00:46:57,150

nobody suspected it before.

1234
00:46:57,150 --> 00:46:58,470
So there's a whole lot of things,

1235
00:46:58,470 --> 00:46:59,700
again, thanks to experiments.

1236
00:46:59,700 --> 00:47:01,920
Without experiments, we cannot
make any of these things

1237
00:47:01,920 --> 00:47:03,450
'cause it'll become very wild

1238
00:47:03,450 --> 00:47:04,283
because people say

1239
00:47:04,283 --> 00:47:06,600
that our consciousness
is quantum mechanical.

1240
00:47:06,600 --> 00:47:08,220
Maybe, but who can prove it?

1241
00:47:08,220 --> 00:47:10,710
But this photosynthesis,

1242
00:47:10,710 --> 00:47:13,380
I was also telling you
the case of only faction.

1243
00:47:13,380 --> 00:47:15,960
In fact I heard a talk in
the same Berkeley meeting

1244
00:47:15,960 --> 00:47:17,669
by Luca Turin.

1245
00:47:17,669 --> 00:47:21,930

So apparently in the theory of
smell or in the experiments,

1246

00:47:21,930 --> 00:47:25,200
a specific molecule corresponds
to a specific smell.

1247

00:47:25,200 --> 00:47:28,050
So it goes and fits like a
lock and key into some enzyme.

1248

00:47:28,050 --> 00:47:30,270
Then there is a chemical reaction

1249

00:47:30,270 --> 00:47:32,580
or a electron transfer reaction.

1250

00:47:32,580 --> 00:47:33,840
And it was experimentally found,

1251

00:47:33,840 --> 00:47:35,760
apparently when the molecule fits,

1252

00:47:35,760 --> 00:47:39,060
there is no such smelling
if the molecule is replaced

1253

00:47:39,060 --> 00:47:40,050
by its isotope,

1254

00:47:40,050 --> 00:47:43,180
for example, if you replace
all the hydrogen atom

1255

00:47:43,180 --> 00:47:44,610
'cause the mass is different.

1256

00:47:44,610 --> 00:47:46,110
then look at it in speculated,

1257

00:47:46,110 --> 00:47:48,610
that somehow the electron transfer

1258

00:47:49,769 --> 00:47:51,090
is phonon assisted tunneling.

1259

00:47:51,090 --> 00:47:53,550
The phonon quantile from the molecule

1260

00:47:53,550 --> 00:47:55,440
is delivered to the electron with jumps,

1261

00:47:55,440 --> 00:47:56,910
but it is not the right quanta.

1262

00:47:56,910 --> 00:47:59,760
So it's a lesson in
tunneling, so smelling stuff.

1263

00:47:59,760 --> 00:48:01,263
and I was very happy to hear

1264

00:48:01,263 --> 00:48:03,510
that that's also getting confirmed.

1265

00:48:03,510 --> 00:48:06,300
So there are many, many
small, small processes,

1266

00:48:06,300 --> 00:48:08,637
there are many such things,
you know, who knows?

1267

00:48:08,637 --> 00:48:11,070
- So there was one that you
mentioned actually in a paper

1268

00:48:11,070 --> 00:48:13,320
that just, I was so fascinated by.

1269
00:48:13,320 --> 00:48:14,880
In one of the papers that you sent us,

1270
00:48:14,880 --> 00:48:16,927
the last paragraph
starts with the sentence,

1271
00:48:16,927 --> 00:48:18,870
"Nature is remarkable."

1272
00:48:18,870 --> 00:48:22,410
And then you give the
example of a snapping shrimp,

1273
00:48:22,410 --> 00:48:26,490
that it snaps its claw,
which creates a sound,

1274
00:48:26,490 --> 00:48:28,920
but then the sound, the bubble collapse

1275
00:48:28,920 --> 00:48:30,570
and it actually creates light.

1276
00:48:30,570 --> 00:48:32,430
And I, first of all, that's amazing to me,

1277
00:48:32,430 --> 00:48:34,800
I didn't know that
shrimp could create light

1278
00:48:34,800 --> 00:48:35,850
by snapping its claw,

1279
00:48:35,850 --> 00:48:39,480
but this is another example

of nature has been at this

1280

00:48:39,480 --> 00:48:40,830

for billions of years

1281

00:48:40,830 --> 00:48:43,862

and we're sort of trying to
catch up with our experiments.

1282

00:48:43,862 --> 00:48:47,067

- See, I was writing that article

1283

00:48:47,067 --> 00:48:49,500

and my professor on his 60th birthday.

1284

00:48:51,017 --> 00:48:54,210

I made the thesis that all
(indistinct) in biology.

1285

00:48:54,210 --> 00:48:55,903

Then as I was finishing that paper,

1286

00:48:55,903 --> 00:48:58,350

I came across this paper in "Nature"

1287

00:48:58,350 --> 00:49:01,200

where sonoluminescence is been made use of

1288

00:49:01,200 --> 00:49:04,380

by biological creatures in the deep ocean.

1289

00:49:04,380 --> 00:49:06,150

And sonoluminescence
according to this researcher

1290

00:49:06,150 --> 00:49:08,820

was discovered 150
years ago by some people

1291
00:49:08,820 --> 00:49:10,290
but nature had it.

1292
00:49:10,290 --> 00:49:12,330
- Yeah, nature's been
doing some of this stuff

1293
00:49:12,330 --> 00:49:15,603
well before we even were
on the scene to examine it.

1294
00:49:16,560 --> 00:49:17,393
- Radical pairing,

1295
00:49:17,393 --> 00:49:21,030
similar to splitting
and quantum coherence,

1296
00:49:21,030 --> 00:49:23,043
nature has evolved and,

1297
00:49:23,043 --> 00:49:24,900
in fact, there are serious people

1298
00:49:24,900 --> 00:49:26,610
working on quantum biology,

1299
00:49:26,610 --> 00:49:28,140
and of course, it's very tough field

1300
00:49:28,140 --> 00:49:30,390
because experiments are very few,

1301
00:49:30,390 --> 00:49:32,640
so you have to collaborate
with the experiment at least.

1302
00:49:32,640 --> 00:49:36,300

Like one mathematician, Roger Penrose,

1303

00:49:36,300 --> 00:49:40,950

he has a hypothesis of
microtubules acting like qubits.

1304

00:49:40,950 --> 00:49:43,260

So microtubules are collection of proteins

1305

00:49:43,260 --> 00:49:44,490

which forms tubes,

1306

00:49:44,490 --> 00:49:47,460

they are like skeletons
of the inside the cell.

1307

00:49:47,460 --> 00:49:49,140

They carry dipole moment.

1308

00:49:49,140 --> 00:49:51,570

So his hypothesis is that this could,

1309

00:49:51,570 --> 00:49:54,840

act electromagnetic mode
of that could like qubit.

1310

00:49:54,840 --> 00:49:57,330

And there are group of people
who are trying to prove it.

1311

00:49:57,330 --> 00:49:58,860

So many people say it's not possible,

1312

00:49:58,860 --> 00:50:00,600

but there's an active discussion.

1313

00:50:00,600 --> 00:50:03,300

So there are some latent speculations

1314
00:50:03,300 --> 00:50:05,070
and there are some wild speculations.

1315
00:50:05,070 --> 00:50:06,960
That's why people shy
away from this field.

1316
00:50:06,960 --> 00:50:10,470
It's not hard field with
experimental evidences,

1317
00:50:10,470 --> 00:50:12,720
someone can easily go astray.

1318
00:50:12,720 --> 00:50:14,070
- And some people do go astray.

1319
00:50:14,070 --> 00:50:15,540
You know, some of these ideas,

1320
00:50:15,540 --> 00:50:17,760
people start to think
of the brain and quantum

1321
00:50:17,760 --> 00:50:20,340
and then pseudoscience
sometimes takes over.

1322
00:50:20,340 --> 00:50:22,156
- Exactly, pseudoscience,
that's the right word, yeah.

1323
00:50:22,156 --> 00:50:23,670
I think it's okay for the public,

1324
00:50:23,670 --> 00:50:25,410
but scientists should not get that,

1325

00:50:25,410 --> 00:50:27,330
and also the public can get swayed,

1326
00:50:27,330 --> 00:50:30,150
because they may start
emphasizing the wrong things.

1327
00:50:30,150 --> 00:50:33,180
I do an experiment, you
should be able to repeat it.

1328
00:50:33,180 --> 00:50:35,910
- I think it's difficult
because this area,

1329
00:50:35,910 --> 00:50:39,060
combining two fields, you know,
quantum physics and biology,

1330
00:50:39,060 --> 00:50:41,880
you've said there's a lot of
problems at that intersection

1331
00:50:41,880 --> 00:50:42,900
that are worth studying.

1332
00:50:42,900 --> 00:50:46,380
But then some, like consciousness,
that at least for now

1333
00:50:46,380 --> 00:50:49,680
are maybe too complicated to
study at that intersection.

1334
00:50:49,680 --> 00:50:51,780
Do you think there are some problems

1335
00:50:51,780 --> 00:50:55,800
that will always be too
complicated to study?

1336

00:50:55,800 --> 00:50:57,360

- Ah, that's a very good question.

1337

00:50:57,360 --> 00:51:02,070

So your question is, will
humanity ever understand mind?

1338

00:51:02,070 --> 00:51:03,780

I suspect, yes.

1339

00:51:03,780 --> 00:51:05,430

You know, the universe is too complex

1340

00:51:05,430 --> 00:51:08,070

and too big to be comprehended.

1341

00:51:08,070 --> 00:51:09,780

Think about just eight billion people,

1342

00:51:09,780 --> 00:51:14,100

each person is own universe,
his own mind, his one richness,

1343

00:51:14,100 --> 00:51:15,960

that's one tiny dot, right?

1344

00:51:15,960 --> 00:51:18,540

And also our own, you
know, this is bacteria.

1345

00:51:18,540 --> 00:51:20,400

The number of bacteria in our body

1346

00:51:20,400 --> 00:51:22,560

is about five times the
number of cells in the body.

1347

00:51:22,560 --> 00:51:25,980
This came as a shock when
I heard it 10 years ago

1348
00:51:25,980 --> 00:51:26,813
during an interview.

1349
00:51:26,813 --> 00:51:28,170
Then I started reading about it.

1350
00:51:28,170 --> 00:51:30,810
It's amazing how we
are helped by bacteria.

1351
00:51:30,810 --> 00:51:33,240
So there is too much to be comprehended.

1352
00:51:33,240 --> 00:51:34,490
Even in condensed meta physics,

1353
00:51:34,490 --> 00:51:36,660
we thought we understand
salt, sodium chloride,

1354
00:51:36,660 --> 00:51:38,220
now we don't understand this.

1355
00:51:38,220 --> 00:51:40,140
Slowly, progress is taking place.

1356
00:51:40,140 --> 00:51:43,260
Nature is inexhaustible and
we have finite lifetime,

1357
00:51:43,260 --> 00:51:44,880
we live for 100 years.

1358
00:51:44,880 --> 00:51:47,340
These days some people say

that from 10 years, onwards.

1359

00:51:47,340 --> 00:51:49,327

No, everybody will live for 100 years

1360

00:51:49,327 --> 00:51:51,417

'cause quality of life is
changing, medicine and so on.

1361

00:51:51,417 --> 00:51:54,360

So, but you know, the
universe is 13 billion years.

1362

00:51:54,360 --> 00:51:56,310

It's already a miracle that
we are able to comprehend.

1363

00:51:56,310 --> 00:51:58,560

As Einstein said, he can't comprehend

1364

00:51:58,560 --> 00:52:00,910

that we can comprehend
little bit of the world.

1365

00:52:02,242 --> 00:52:04,410

- Well it sounds like
you have just as many,

1366

00:52:04,410 --> 00:52:07,320

if not more questions in your head now

1367

00:52:07,320 --> 00:52:09,150

than you did when you were starting out

1368

00:52:09,150 --> 00:52:11,010

- Definitely, exactly, exactly.

1369

00:52:11,010 --> 00:52:12,627

- So a lifetime of science,

1370

00:52:12,627 --> 00:52:13,800
but now you're left with more

1371

00:52:13,800 --> 00:52:15,390
questions than you started with?

1372

00:52:15,390 --> 00:52:16,770
- Definitely.

1373

00:52:16,770 --> 00:52:19,343
- Is that part of the joy of it?

1374

00:52:19,343 --> 00:52:20,400
- So you understand a little bit of it,

1375

00:52:20,400 --> 00:52:24,450
then you don't understand
more and excitement continues.

1376

00:52:24,450 --> 00:52:26,160
It's also question of training oneself.

1377

00:52:26,160 --> 00:52:27,030
You know, I have the habit

1378

00:52:27,030 --> 00:52:30,510
of spending half an hour every
day looking at the archive.

1379

00:52:30,510 --> 00:52:32,037
I tell young people to do that.

1380

00:52:32,037 --> 00:52:33,480
- Oh, that's the pre-print site

1381

00:52:33,480 --> 00:52:35,040
for all the new physics papers?

1382

00:52:35,040 --> 00:52:36,960

- So I can't do all of
them, I am very choosy,

1383

00:52:36,960 --> 00:52:38,400

strongly correlated systems

1384

00:52:38,400 --> 00:52:40,800

and super connectivity
and quantum physics,

1385

00:52:40,800 --> 00:52:42,210

I download few papers.

1386

00:52:42,210 --> 00:52:45,330

It's exciting to see how
developments are taking place.

1387

00:52:45,330 --> 00:52:47,280

It provokes your thought,
you start thinking about,

1388

00:52:47,280 --> 00:52:49,560

and some of it, all the
crazy ideas are at work,

1389

00:52:49,560 --> 00:52:51,420

so you feel happy about it, satisfied.

1390

00:52:51,420 --> 00:52:53,653

You didn't write that paper, it's okay.

1391

00:52:53,653 --> 00:52:55,530

- Yeah, you know one thing
that really stood out to me

1392

00:52:55,530 --> 00:52:56,880

from our earlier discussion,

1393

00:52:56,880 --> 00:53:00,360

you said that you have a lot
of folders on your computer

1394

00:53:00,360 --> 00:53:04,680

that contain unfinished projects
and I think that's great,

1395

00:53:04,680 --> 00:53:06,090

you know that your interests are so broad

1396

00:53:06,090 --> 00:53:07,200

and there's so many questions

1397

00:53:07,200 --> 00:53:08,970

and sometimes you don't
end up answering them,

1398

00:53:08,970 --> 00:53:10,260

of course, sometimes you do.

1399

00:53:10,260 --> 00:53:12,600

I'm just curious if there
are some of those projects

1400

00:53:12,600 --> 00:53:14,220

that you look back on

1401

00:53:14,220 --> 00:53:16,080

and find yourself still wondering about

1402

00:53:16,080 --> 00:53:17,880

that you might go back to someday.

1403

00:53:17,880 --> 00:53:20,130

- Yeah, yeah, it very often happens.

1404

00:53:20,130 --> 00:53:21,390
You think of something,

1405
00:53:21,390 --> 00:53:24,600
you start writing a pre-print
and you leave it there.

1406
00:53:24,600 --> 00:53:27,150
You haven't forgotten
the name of the paper.

1407
00:53:27,150 --> 00:53:29,520
In fact, it's a good
point I should mention

1408
00:53:29,520 --> 00:53:31,230
because it's like a public promise.

1409
00:53:31,230 --> 00:53:34,260
See, great Einstein wrote a paper in 1920

1410
00:53:34,260 --> 00:53:36,000
before quantum mechanics was born,

1411
00:53:36,000 --> 00:53:37,920
a theory of super conductivity.

1412
00:53:37,920 --> 00:53:39,540
Not many people know about it

1413
00:53:39,540 --> 00:53:42,150
and a good person from
Germany translated it

1414
00:53:42,150 --> 00:53:44,730
and so Einstein's paper is in the archive.

1415
00:53:44,730 --> 00:53:46,230
When I read that paper, I was shocked

1416
00:53:46,230 --> 00:53:48,210
because Einstein was so ahead of time.

1417
00:53:48,210 --> 00:53:52,110
He says, okay, so here is a
phenomena, zero resistance.

1418
00:53:52,110 --> 00:53:53,880
I know what is Drude's law,

1419
00:53:53,880 --> 00:53:55,320
there are electrons which are starting,

1420
00:53:55,320 --> 00:53:56,820
they have some lifetime.

1421
00:53:56,820 --> 00:54:01,820
And then he says totally
away from any Drude's law

1422
00:54:02,130 --> 00:54:03,690
it's something totally different.

1423
00:54:03,690 --> 00:54:05,700
So he comes to the conclusion

1424
00:54:05,700 --> 00:54:07,740
that our normal metal is a puzzle,

1425
00:54:07,740 --> 00:54:10,320
it should be thought of as
a perturbed superconductor.

1426
00:54:10,320 --> 00:54:11,520
So he completely reverses.

1427
00:54:11,520 --> 00:54:13,500

He says, "You should understand normal metal."

1428
00:54:13,500 --> 00:54:16,410
And that is what the game in superconductivity is.

1429
00:54:16,410 --> 00:54:18,360
Then normal metal is very unusual

1430
00:54:18,360 --> 00:54:20,610
it's called anomalous normal.

1431
00:54:20,610 --> 00:54:23,400
And then on top of that, what he could think of

1432
00:54:23,400 --> 00:54:25,740
with available resources and knowledge.

1433
00:54:25,740 --> 00:54:28,692
So he says, okay, here is a phenomena that I see

1434
00:54:28,692 --> 00:54:30,210
(indistinct)

1435
00:54:30,210 --> 00:54:31,380
so how could it be?

1436
00:54:31,380 --> 00:54:33,270
So he thinks of an electron

1437
00:54:33,270 --> 00:54:35,040
hopping from one site to another site.

1438
00:54:35,040 --> 00:54:36,810
Then there'll be strong, cool repulsion.

1439
00:54:36,810 --> 00:54:38,790
Next electron will not allow you to come.

1440
00:54:38,790 --> 00:54:40,623
So it will push the other electron,

1441
00:54:40,623 --> 00:54:42,330
it will push it so they'll form a cycle.

1442
00:54:42,330 --> 00:54:45,450
So you call it as a cyclic
exchange, I forget the name.

1443
00:54:45,450 --> 00:54:48,330
So he says, under some
conditions, the electron's motion

1444
00:54:48,330 --> 00:54:51,060
will not be independent, but
it will be cyclic motion,

1445
00:54:51,060 --> 00:54:52,500
and maybe that is under that.

1446
00:54:52,500 --> 00:54:53,520
In fact, it's very true.

1447
00:54:53,520 --> 00:54:54,930
In fact, the whole quantum hall effect

1448
00:54:54,930 --> 00:54:58,080
and many of these things are
related to phenomena like that.

1449
00:54:58,080 --> 00:54:59,640
So Einstein thought about it.

1450
00:54:59,640 --> 00:55:01,290

In fact, in the context of quantum hall,

1451

00:55:01,290 --> 00:55:02,580

this is something ring exchange theory

1452

00:55:02,580 --> 00:55:04,200

due to Schafer and company.

1453

00:55:04,200 --> 00:55:06,240

So this collective cooperating

1454

00:55:06,240 --> 00:55:08,670

motion of electrons in the form of rings

1455

00:55:08,670 --> 00:55:11,910

is according to Einstein at the heart of super conductivity.

1456

00:55:11,910 --> 00:55:14,220

In fact, it is related to later

1457

00:55:14,220 --> 00:55:15,660

something called permutation cycles

1458

00:55:15,660 --> 00:55:17,760

that happens in both systems.

1459

00:55:17,760 --> 00:55:20,730

So I had written an article

1460

00:55:20,730 --> 00:55:23,400

connecting Einstein's old theory with modern theory,

1461

00:55:23,400 --> 00:55:25,083

and I just saw it yesterday.

1462

00:55:26,228 --> 00:55:28,260

I felt like kicking
myself, it's 10 years ago,

1463
00:55:28,260 --> 00:55:29,093
I didn't do anything.

1464
00:55:29,093 --> 00:55:30,330
So to answer your question-

1465
00:55:30,330 --> 00:55:32,340
- So you saw it on your
computer, not published,

1466
00:55:32,340 --> 00:55:33,240
it's an unfinished?

1467
00:55:33,240 --> 00:55:35,229
- Exactly, it's a tech file.

1468
00:55:35,229 --> 00:55:37,560
I started it and just halfway.

1469
00:55:37,560 --> 00:55:38,580
- Well, maybe over time

1470
00:55:38,580 --> 00:55:41,430
if you leave a paper for
a year or five years,

1471
00:55:41,430 --> 00:55:42,660
does your brain,

1472
00:55:42,660 --> 00:55:45,330
you know, the things that
you've learned over that time,

1473
00:55:45,330 --> 00:55:47,880
you can approach the subject
after a break from it

1474
00:55:47,880 --> 00:55:49,590
with a different perspective?

1475
00:55:49,590 --> 00:55:50,423
- That's right.

1476
00:55:50,423 --> 00:55:52,290
Sometimes, you know, I
find that I was wrong,

1477
00:55:52,290 --> 00:55:56,772
but sometimes I find I'm
more right, it happens.

1478
00:55:56,772 --> 00:55:58,110
- Well, it seems too
from what I understand,

1479
00:55:58,110 --> 00:56:01,440
that going to talks and also
having discussions with people

1480
00:56:01,440 --> 00:56:03,840
is such an important part
of your research for you.

1481
00:56:03,840 --> 00:56:07,440
you mentioned going to
Nicole Younger Halpern's talk

1482
00:56:07,440 --> 00:56:09,030
and it gave you some idea

1483
00:56:09,030 --> 00:56:10,680
that's maybe related to some other things

1484
00:56:10,680 --> 00:56:11,850
you have been thinking about.

1485

00:56:11,850 --> 00:56:14,460
And so I guess maybe that's
also something that can happen,

1486

00:56:14,460 --> 00:56:16,710
you attend to talk and
that gives you an idea

1487

00:56:16,710 --> 00:56:19,020
for one of those unfinished projects.

1488

00:56:19,020 --> 00:56:19,853
- That's right.

1489

00:56:19,853 --> 00:56:21,690
So for some reason I was
searching for something,

1490

00:56:21,690 --> 00:56:25,170
then I landed on my paper and
it made me sad for a while,

1491

00:56:25,170 --> 00:56:27,544
but then I said, okay, it's fine.

1492

00:56:27,544 --> 00:56:28,840
- We've been talking a lot

1493

00:56:28,840 --> 00:56:31,410
about how your interests are so broad,

1494

00:56:31,410 --> 00:56:33,240
but I've been wondering if there's,

1495

00:56:33,240 --> 00:56:35,490
is there an idea that
maybe ties them together?

1496
00:56:35,490 --> 00:56:37,740
And maybe I'm wrong, but
I wonder if the idea-

1497
00:56:37,740 --> 00:56:39,180
- Is there an identifying theme?

1498
00:56:39,180 --> 00:56:41,730
- Yeah, that maybe understanding emergence

1499
00:56:41,730 --> 00:56:44,130
is somehow some kind of
theme in all this work.

1500
00:56:44,130 --> 00:56:45,510
Would you say that that's something

1501
00:56:45,510 --> 00:56:47,827
that's tying all of this together?

1502
00:56:47,827 --> 00:56:51,840
- Yeah, I think partly influenced
by PW Anderson's career

1503
00:56:51,840 --> 00:56:54,390
and his works and so on.

1504
00:56:54,390 --> 00:56:55,770
Emergence fascinates me.

1505
00:56:55,770 --> 00:56:58,800
In biology, emergence is very obvious

1506
00:56:58,800 --> 00:57:00,960
because you have atoms,
molecules, water molecules,

1507
00:57:00,960 --> 00:57:02,460

and then many things happen,

1508

00:57:02,460 --> 00:57:05,580

there are insects of
millions and billions types.

1509

00:57:05,580 --> 00:57:09,300

So we say that over billions
of years, these things happen.

1510

00:57:09,300 --> 00:57:12,240

You could not have predicted
next level what will happen

1511

00:57:12,240 --> 00:57:13,980

by knowing what you know now.

1512

00:57:13,980 --> 00:57:15,810

There is a famous evolutionary biologist

1513

00:57:15,810 --> 00:57:17,490

by the name Ernst Meyer.

1514

00:57:17,490 --> 00:57:20,580

He and Neils Bohr discuss emergence.

1515

00:57:20,580 --> 00:57:22,290

Apparently Ernst Meyer was bragging

1516

00:57:22,290 --> 00:57:24,240

about emergence in biology.

1517

00:57:24,240 --> 00:57:26,370

Neils Bohr said, "The whole
physics is emergence."

1518

00:57:26,370 --> 00:57:28,020

He said, "Hydrogen atom."

1519
00:57:28,020 --> 00:57:30,240
Then he suppose, you know
hydrogen atom very well.

1520
00:57:30,240 --> 00:57:32,040
So put hydrogen atoms
together, two of them,

1521
00:57:32,040 --> 00:57:34,113
it becomes hydrogen
molecule, tightly bound.

1522
00:57:34,113 --> 00:57:37,350
Then put a water, oxygen
than it become H₂O.

1523
00:57:37,350 --> 00:57:39,567
Then put few water molecules together,

1524
00:57:39,567 --> 00:57:42,000
there is tendency to form hydrogen bound

1525
00:57:42,000 --> 00:57:43,410
and quantum tunneling.

1526
00:57:43,410 --> 00:57:45,660
Then put more together,
you get water droplet.

1527
00:57:45,660 --> 00:57:48,270
Then you freeze them,
you get 12 phases of ice.

1528
00:57:48,270 --> 00:57:51,060
Then you flow, let the water
flow, then you get turbulence,

1529
00:57:51,060 --> 00:57:53,790
which is one of the most

difficult mathematical problems.

1530

00:57:53,790 --> 00:57:56,220

So you have clouds and all kinds of things

1531

00:57:56,220 --> 00:58:00,300

emerges from oxygen and water
in various associations.

1532

00:58:00,300 --> 00:58:03,810

So he views physics as full of emergence.

1533

00:58:03,810 --> 00:58:05,280

While people appreciate it,

1534

00:58:05,280 --> 00:58:06,720

it was not part of the conscience

1535

00:58:06,720 --> 00:58:08,070

of condensed matter community.

1536

00:58:08,070 --> 00:58:11,130

It is here Anderson wrote a paper in 1972,

1537

00:58:11,130 --> 00:58:12,150

more is different.

1538

00:58:12,150 --> 00:58:13,640

Actually, it was a response

1539

00:58:13,640 --> 00:58:16,290

to some of the attitudes of colleagues

1540

00:58:16,290 --> 00:58:18,810

saying that including great men,

1541

00:58:18,810 --> 00:58:19,857

supposed to have said that no,

1542
00:58:19,857 --> 00:58:21,210
now you have the right equation,

1543
00:58:21,210 --> 00:58:22,410
the rest is chemistry.

1544
00:58:22,410 --> 00:58:23,550
You don't need to understand anything.

1545
00:58:23,550 --> 00:58:24,840
You know, science is done.

1546
00:58:24,840 --> 00:58:26,820
Some great person, the end of science,

1547
00:58:26,820 --> 00:58:30,360
you know, the rest is a matter of detail.

1548
00:58:30,360 --> 00:58:32,407
And Anderson took that as
a challenge and he said,

1549
00:58:32,407 --> 00:58:33,480
"No, that is not true.

1550
00:58:33,480 --> 00:58:36,300
Nothing ends, new things
continue to emerge."

1551
00:58:36,300 --> 00:58:39,510
He caught onto this notion
of symmetry breaking

1552
00:58:39,510 --> 00:58:41,670
because you can organize many
things in condensed matter,

1553

00:58:41,670 --> 00:58:43,380
you can develop symmetry breaking.

1554
00:58:43,380 --> 00:58:44,790
And whenever there is a symmetry breaking,

1555
00:58:44,790 --> 00:58:47,310
there is a new rigidity
that brings a new physics.

1556
00:58:47,310 --> 00:58:49,170
And then he went across fields.

1557
00:58:49,170 --> 00:58:52,890
He says, everything has
its own important place

1558
00:58:52,890 --> 00:58:56,580
and you cannot say that it
can be discovered on its own.

1559
00:58:56,580 --> 00:58:58,500
It needs to come from something below.

1560
00:58:58,500 --> 00:59:00,780
And then there are surprises.

1561
00:59:00,780 --> 00:59:03,450
This is also I think some people
call it the web of science,

1562
00:59:03,450 --> 00:59:05,010
connection between various things.

1563
00:59:05,010 --> 00:59:06,960
So emergence fascinates me.

1564
00:59:06,960 --> 00:59:10,170
I can't understand my own way,

1565
00:59:10,170 --> 00:59:15,060
emergence of consciousness and life.

1566
00:59:15,060 --> 00:59:16,260
Life is what we see,

1567
00:59:16,260 --> 00:59:19,140
but things like consciousness
too personal and too,

1568
00:59:19,140 --> 00:59:21,360
they call it qualia and so on.

1569
00:59:21,360 --> 00:59:23,070
I used to have discussion
with Phil Anderson.

1570
00:59:23,070 --> 00:59:25,830
He will say that that's emergence,

1571
00:59:25,830 --> 00:59:28,830
you can't comprehend it, doesn't
mean that it doesn't exist.

1572
00:59:28,830 --> 00:59:30,690
So people have strong views.

1573
00:59:30,690 --> 00:59:32,100
But the emergence that I see

1574
00:59:32,100 --> 00:59:34,080
in my little field of
condensed matter physics

1575
00:59:34,080 --> 00:59:34,950
is mind boggling.

1576

00:59:34,950 --> 00:59:36,750
For example, thanks to Anderson,

1577
00:59:36,750 --> 00:59:38,580
he start identify quantum state

1578
00:59:38,580 --> 00:59:40,410
called resonating valance ground state,

1579
00:59:40,410 --> 00:59:43,380
which was discovered by
Pauling in a different context

1580
00:59:43,380 --> 00:59:45,420
as something very
important for insulators.

1581
00:59:45,420 --> 00:59:47,940
So he wrote it in '73, and
then in the context of qupids,

1582
00:59:47,940 --> 00:59:50,490
he brought it, fortunately
for me, I was with him.

1583
00:59:50,490 --> 00:59:52,000
We developed it and so on.

1584
00:59:52,000 --> 00:59:54,420
Look at the way the field has grown.

1585
00:59:54,420 --> 00:59:56,190
People may have forgotten Anderson,

1586
00:59:56,190 --> 00:59:58,860
but for example, one
of the most complicated

1587
00:59:58,860 --> 01:00:00,870

field in mathematics is
called category theory.

1588

01:00:00,870 --> 01:00:02,490
People tell me, even pure mathematicians

1589

01:00:02,490 --> 01:00:03,960
call it abstract.

1590

01:00:03,960 --> 01:00:07,770
Now, category theory, thanks
to our friend Zalgon Wen

1591

01:00:07,770 --> 01:00:10,360
who classified resonating
valence ground state

1592

01:00:11,341 --> 01:00:12,750
and then trying to organize SPT states,

1593

01:00:12,750 --> 01:00:15,360
he used category theory very casually.

1594

01:00:15,360 --> 01:00:18,210
Now category theory is corner
of condensed metaphysics.

1595

01:00:18,210 --> 01:00:20,130
So nobody would've thought
that it'd be useful.

1596

01:00:20,130 --> 01:00:22,470
And once you got that, many things emerge.

1597

01:00:22,470 --> 01:00:24,870
I can't even understand
what is going on there.

1598

01:00:24,870 --> 01:00:26,790

I wrote an article about graphene.

1599

01:00:26,790 --> 01:00:29,700

I had a page containing
quantum complexity in graphene.

1600

01:00:29,700 --> 01:00:31,590

there is just carbon atom,

1601

01:00:31,590 --> 01:00:34,590

then it's capable of harming SP2 bonding

1602

01:00:34,590 --> 01:00:36,570

or SP3 or SP1 bonding.

1603

01:00:36,570 --> 01:00:38,520

If you go to SP3, you get diamond.

1604

01:00:38,520 --> 01:00:41,940

Then if you go to SP2 alone,
then you get graphene.

1605

01:00:41,940 --> 01:00:44,490

because the bonds are 120 degree

1606

01:00:44,490 --> 01:00:47,310

and there is an unbonded piece at orbital,

1607

01:00:47,310 --> 01:00:49,110

there is a hopping in honeycomb lattice

1608

01:00:49,110 --> 01:00:50,790

that leads to daracon.

1609

01:00:50,790 --> 01:00:53,546

Because there are daracon,
there are two daracon's,

1610

01:00:53,546 --> 01:00:54,990
(speaking in foreign language),

1611
01:00:54,990 --> 01:00:58,350
and the daracon's, there
is a parity anomaly

1612
01:00:58,350 --> 01:01:01,500
and there is anti Anderson
localization and defects,

1613
01:01:01,500 --> 01:01:05,220
acting like age fields
and then lake effects.

1614
01:01:05,220 --> 01:01:06,630
If you think about carbon alone,

1615
01:01:06,630 --> 01:01:08,130
I would not have guessed
that there is room

1616
01:01:08,130 --> 01:01:10,110
for composite pharmacy

1617
01:01:10,110 --> 01:01:13,830
So in level of few steps,
you can reach that level.

1618
01:01:13,830 --> 01:01:15,360
So I am fascinated.

1619
01:01:15,360 --> 01:01:19,020
I think similarly, Wojciech
has a very fascinating thing

1620
01:01:19,020 --> 01:01:21,120
about emergence and liquid helium three.

1621

01:01:21,120 --> 01:01:22,650
In fact, I think he has a nice title

1622
01:01:22,650 --> 01:01:25,230
that you can see the universe
in a droplet of helium three,

1623
01:01:25,230 --> 01:01:27,120
because helium three is a helium,

1624
01:01:27,120 --> 01:01:28,770
you know, isotope of helium atom.

1625
01:01:29,612 --> 01:01:30,600
Put them together, you get liquid helium

1626
01:01:30,600 --> 01:01:33,480
and then they exhibit some
variety of quantum phase,

1627
01:01:33,480 --> 01:01:37,500
super helium three, Anderson
phase, moral phase and so on.

1628
01:01:37,500 --> 01:01:38,607
And to look at them, there is,

1629
01:01:38,607 --> 01:01:41,760
you see the effective theory
looks like quantum gravity.

1630
01:01:41,760 --> 01:01:43,380
So that's a good example of emergence

1631
01:01:43,380 --> 01:01:46,500
in one component system,
Helium three alone.

1632
01:01:46,500 --> 01:01:47,820

That fascinates me.

1633

01:01:47,820 --> 01:01:50,100

Even before going to living systems,

1634

01:01:50,100 --> 01:01:52,380

animated systems offered so much variety.

1635

01:01:52,380 --> 01:01:54,071

Now thanks to material science,

1636

01:01:54,071 --> 01:01:56,160

so we should continue to thank
our experimental colleagues.

1637

01:01:56,160 --> 01:01:58,110

They make all kinds of materials,

1638

01:01:58,110 --> 01:01:59,070

starting with graphene,

1639

01:01:59,070 --> 01:02:00,287

now they have (indistinct).

1640

01:02:01,590 --> 01:02:02,910

Each one is a miracle.

1641

01:02:02,910 --> 01:02:04,710

People skip away and go into mathematics,

1642

01:02:04,710 --> 01:02:06,090

but we have to listen to phenomenons,

1643

01:02:06,090 --> 01:02:08,730

there are lots and lots
of fascinating things.

1644

01:02:08,730 --> 01:02:10,290

- You've used that word fascinating

1645

01:02:10,290 --> 01:02:13,590
to describe your own reaction
to learning new things.

1646

01:02:13,590 --> 01:02:15,240
I think that's what's come through

1647

01:02:15,240 --> 01:02:17,730
in chatting with you last week and today

1648

01:02:17,730 --> 01:02:21,570
is that your curiosity is just
almost insatiable it seems,

1649

01:02:21,570 --> 01:02:25,410
and that you have this
gratitude for science

1650

01:02:25,410 --> 01:02:26,910
and its place in your life.

1651

01:02:26,910 --> 01:02:28,977
And that's why I think
people here at Perimeter

1652

01:02:28,977 --> 01:02:31,130
are so excited to sit down with you

1653

01:02:31,130 --> 01:02:34,620
is that gratitude and
enthusiasm feel infectious,

1654

01:02:34,620 --> 01:02:37,020
that you're helping other
people like us get excited.

1655

01:02:37,020 --> 01:02:39,419

- Yeah, I'm grateful to science.

1656

01:02:39,419 --> 01:02:40,800

You know, I'm happy that
I became a scientist.

1657

01:02:40,800 --> 01:02:44,550

II also often say that
I'm paid for my enjoyment.

1658

01:02:44,550 --> 01:02:45,750

What else do you expect?

1659

01:02:45,750 --> 01:02:47,617

I very often talk to friends that tell me,

1660

01:02:47,617 --> 01:02:49,463

"you know, when are you going to retire?

1661

01:02:49,463 --> 01:02:51,147

You are still studying."

1662

01:02:52,320 --> 01:02:54,090

I have no time actually.

1663

01:02:54,090 --> 01:02:56,610

There are no so many things
to be understood and enjoyed.

1664

01:02:56,610 --> 01:02:58,380

- You don't have time to retire.

1665

01:02:58,380 --> 01:03:00,780

- Exactly, I have no time to retire.

1666

01:03:00,780 --> 01:03:02,640

- That's a good way to put it.

1667

01:03:02,640 --> 01:03:05,280
Well, we're very grateful
that you've taken the time

1668
01:03:05,280 --> 01:03:06,450
to sit down and talk with us.

1669
01:03:06,450 --> 01:03:09,600
I feel so inspired to
read more and learn more.

1670
01:03:09,600 --> 01:03:10,980
Thank you so much for taking the time.

1671
01:03:10,980 --> 01:03:12,080
- Thank you very much.

1672
01:03:15,120 --> 01:03:17,880
- Thanks for listening to
Conversations at The Perimeter.

1673
01:03:17,880 --> 01:03:18,840
If you like what you hear,

1674
01:03:18,840 --> 01:03:20,760
please help us spread the word.

1675
01:03:20,760 --> 01:03:23,610
Rate, review and subscribe
to Conversations at Perimeter

1676
01:03:23,610 --> 01:03:25,650
wherever you get your podcasts.

1677
01:03:25,650 --> 01:03:27,840
Every review helps us out a lot

1678
01:03:27,840 --> 01:03:30,570
and it helps more science

enthusiasts find us.

1679

01:03:30,570 --> 01:03:32,470

Thanks for being part of the equation.